SIXTH EDITION

RADIOGRAPHIC IMAGE ANALYSIS

Kathy McQuillen Martensen

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Radiographic Image Analysis

SIXTH EDITION

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Dedication

To my husband, Van, who has never failed to be my greatest supporter and assistant. He knows as much about x-ray positioning and evaluation as I do after being my sounding board for so many years. Thanks, hon.

Preface

This textbook serves as a practical image analysis and procedure reference for radiography educators, students, and technologists by providing information to correlate the technical and positioning procedures with the image analysis guidelines for common projections; adjust the procedural setup for patient condition variations, for nonroutine situations, and when a less-than-optimal projection is obtained; develop a high degree of radiography problem-solving ability; and prepare for the radiography ARRT examination.

This Edition

In this edition the procedural positioning photographs have been updated to digital radiography, additional procedures have been added and gonadal shielding has been removed to meet the ARRT examination specifications, and the chapter on the Digestive System has been removed to limit the focus of the textbook to skeletal radiography.

Chapters 1 and 2 lay the foundation for evaluating all projections, outlining the technical and digital imaging concepts that are to be considered when studying the procedures presented in the subsequent chapters.

Chapters 3 through 11 detail the image analysis guidelines for commonly performed radiographic procedures. For each procedure presented, this

edition provides the following:

- Accurately positioned projections with labeled anatomy.
- Photographs of accurately positioned models.
- Tables that provide a detailed one-to-one correlation between the positioning procedures and the image analysis guidelines.
- Discussions, with correlating projections, on identifying how the patient, central ray, or image receptor was poorly positioned if the projection does not demonstrate an image analysis guideline.
- Discussions of topics relating to positioning for patient condition variations and nonroutine situations.
- Illustrations and photographs of bones and models, positioned to clarify information and demonstrate anatomy alignment when distortion makes it difficult.
- Practice projections that demonstrate common procedural errors.

Acknowledgments

My deepest appreciation and thanks go to the following for help with this edition.

Ellie Brittingham for capturing and editing the new positioning photographs; Jesse Brennan for organizing and assisting with the photography; Hannah Feuerhelm, Sydney Grouwinkel, and Makenna Curtis for modeling the positions; and the University of Iowa Hospitals and Clinics' Radiology Department for the use of their facility.

Stephanie Harris, for updating the accompanying Radiographic Image Analysis Workbook.

Sonya Seigafuse, Meg Benson, Vaishali Singh, Sindhuraj Thulasingam, and the entire Elsevier team for their support, assistance, and expertise in planning and developing this project.

With this being my final edition, I'd like to thank all the professional colleagues, educators, technologists, and UIHC Radiologic Technology students who have utilized the textbook over the many editions. It has been my honor to have assisted you in understanding radiographic positioning and analysis.

Chapter 1: Guidelines for Image Analysis

OBJECTIVES

AFTER COMPLETION OF THIS CHAPTER, YOU SHOULD BE ABLE TO DO THE FOLLOWING:

- STATE THE CHARACTERISTICS OF AN OPTIMAL PROJECTION.
- PROPERLY DISPLAY PROJECTIONS OF ALL BODY STRUCTURES.
- STATE HOW THE PATIENT IS ASSOCIATED WITH THE PROJECTIONS AND EXPLAIN WHAT TO DO IF THERE IS A MISASSOCIATION.
- DISCUSS HOW TO MARK PROJECTIONS ACCURATELY AND EXPLAIN THE PROCEDURE TO BE FOLLOWED IF A PROJECTION HAS BEEN MISMARKED OR THE MARKER IS ONLY FAINTLY SEEN.
- DISCUSS WHY GOOD COLLIMATION PRACTICES ARE NECESSARY AND LIST THE GUIDELINES TO FOLLOW TO ENSURE GOOD COLLIMATION.
- DESCRIBE HOW POSITIONING OF ANATOMIC STRUCTURES IN REFERENCE TO THE CENTRAL RAY (CR) AND IMAGE RECEPTOR (IR) AFFECTS

HOW THEY ARE VISUALIZED ON THE RESULTING PROJECTION.

- STATE HOW SIMILARLY APPEARING STRUCTURES CAN BE IDENTIFIED ON PROJECTIONS.
- DETERMINE THE AMOUNT OF PATIENT OR CR ADJUSTMENT REQUIRED WHEN POORLY POSITIONED PROJECTIONS ARE OBTAINED.
- DISCUSS THE FACTORS THAT AFFECT THE SPATIAL RESOLUTION IN A PROJECTION.
- DESCRIBE THE RADIATION PROTECTION PRACTICES THAT ARE FOLLOWED TO LIMIT PATIENT AND PERSONNEL DOSE.

KEY TERMS **ALARA ANTERIOR BACKUP TIMER CONTRAST MASK DECUBITUS DETECTOR ELEMENT (DEL) DISTORTION DOSE CREEP DOSE EQUIVALENT LIMIT DOUBLE EXPOSURE ELONGATION EXPOSURE MAINTENANCE FORMULA FIELD OF VIEW (FOV) FLEXION FOCAL SPOT FORESHORTENING GEOMETRIC FACTORS GRID GRID CUTOFF IMAGE RECEPTOR (IR) INVERSE SQUARE LAW INVOLUNTARY MOTION LATERAL MAGNIFICATION FORMULA MATRIX MEDIAL MIDCORONAL PLANE MIDSAGITTAL PLANE MOTION UNSHARPNESS NONSTOCHASTIC EFFECTS OBJECT–IMAGE RECEPTOR DISTANCE (OID) PICTURE ARCHIVAL AND COMMUNICATION SYSTEM (PACS) PIXEL POSTERIOR PROFILE PROJECT RADIOLUCENT RADIOPAQUE RECORDED DETAIL SCATTER RADIATION SIZE DISTORTION SOURCE–IMAGE RECEPTOR DISTANCE (SID) SOURCE-SKIN DISTANCE**

Why Image Analysis?

Radiographic projections are such that slight differences in quality do not necessarily rule out their diagnostic value. Reviewers can ordinarily make satisfactory adjustments by reason of their experience and knowledge, although passing less than optimal projections may compromise the diagnosis and treatment and result in additional projections at a higher expense and radiation dose to the patient. The purpose of image analysis is to explore how to evaluate projections for acceptability, determine how to improve positioning and technical skills before repeating a projection, and continually improve skills.

Why does a technologist care about creating optimal projections and studying all the small details relating to image analysis? The most important answer to this question lies in why most technologists join the profession—to help people. From the patient's point of view, it provides the reviewer with projections that contain optimal diagnostic value, prevents the anxiety that occurs when additional projections or studies need to be performed, and prevents the radiation dosage that might be caused by additional imaging. From a societal point of view, it helps to prevent additional increases in health care costs that could result because of the need for additional, more expensive imaging procedures and because of the malpractice cases that might result from a poor or missed diagnosis. From a technologist's point of view, it would be the preventable financial burden and stress that arise from legal actions, a means of protecting professional interest as more diagnostic procedures are being replaced with other

modalities, and the personal satisfaction gained when our patients, employer, and ourselves benefit from and are recognized for our expertise.

Consider how accuracy in positioning and technical factors affect the diagnostic value of a projection. Chest procedures are one of the most commonly performed projections each year. They are completed to evaluate the lungs, heart, and thoracic viscera, as well as disease processes such as pneumonia, heart failure, pleurisy, and lung cancer. The reviewer must consider all the normal variations that exist in areas such as the mediastinum, hila, diaphragm, and lungs. Should they also have to consider how the appearance of these structures is different with preventable positioning and technical errors? It takes only 2 or 3 degrees of rotation to affect the appearance of the lungs, causing differences in brightness values along the lateral borders of the chest projection (**Fig. 1.1**). Similarly, certain conditions such as mediastinal widening or cardiac size cannot be evaluated properly on a rotated posteroanterior (PA) chest projection. The normal heart shadow on such a projection will occupy slightly less than 50% of the transverse dimension of the thorax (**Fig. 1.2**). This is evaluated by measuring the largest transverse diameter of the heart on the PA or anteroposterior (AP) projection and relating that to the largest transverse measurement of the internal dimension of the chest. When the PA chest projection is rotated, bringing a different heart plane into profile, this diagnosis becomes compromised.

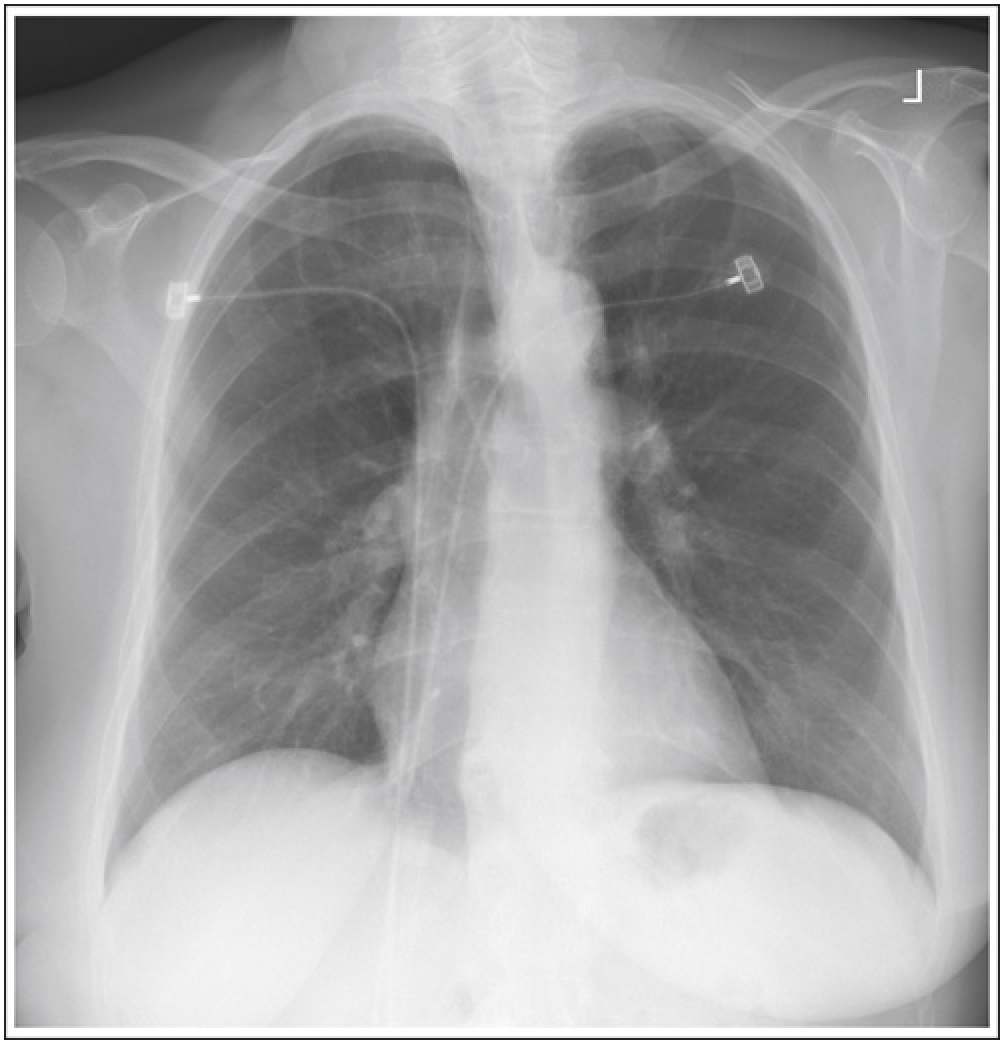


FIGURE 1.1 Rotated PA chest projection.

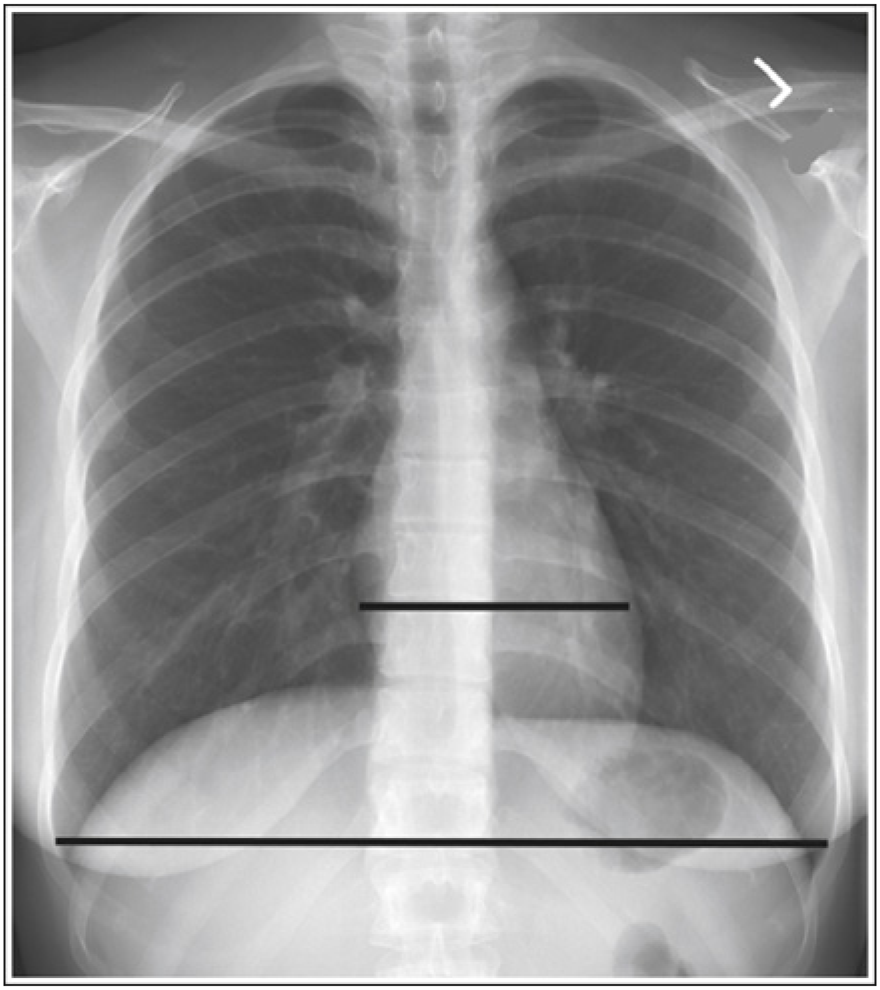


FIGURE 1.2 Evaluating a PA chest projection for mediastinal widening.

If instead of being evaluated for acceptability, projections are evaluated for optimalism, could more consistent and improved diagnoses be made from diagnostic projections? Figs. **1.3** and **1.4** demonstrate three lateral and PA wrist projections, all of which were determined to be acceptable and sent to the reviewer for diagnosis. Note how the trapezium is visualized only on the first lateral wrist projection but is not demonstrated on the other two, and observe how the carpometacarpal joints and distal carpal bones are well visualized on the first PA wrist projection but are not seen on the other two projections. The first lateral wrist projection was obtained with the

thumb depressed until the first metacarpal (MC) was aligned with the second MC, whereas the other lateral wrist projections were obtained with the first MC elevated. The first PA wrist projection was obtained with the MCs aligned at a 10- to 15-degree angle with the image receptor (IR), the second PA wrist projection was taken with the MCs aligned at an angle greater than 15 degrees, and the third projection was taken with the MCs aligned at an angle less than 10 degrees. If the radiologist cannot arrive at a conclusive diagnosis from the projections that the technologist provides, he or she must recommend other imaging procedures or follow-up projections.

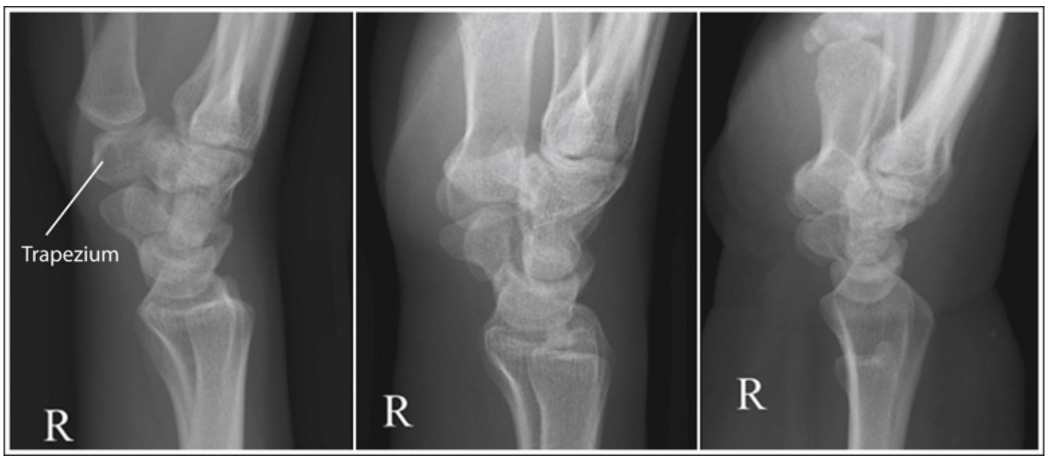


FIGURE 1.3 Lateral wrist projections demonstrating the difference in trapezium visualization with thumb depression and elevation.

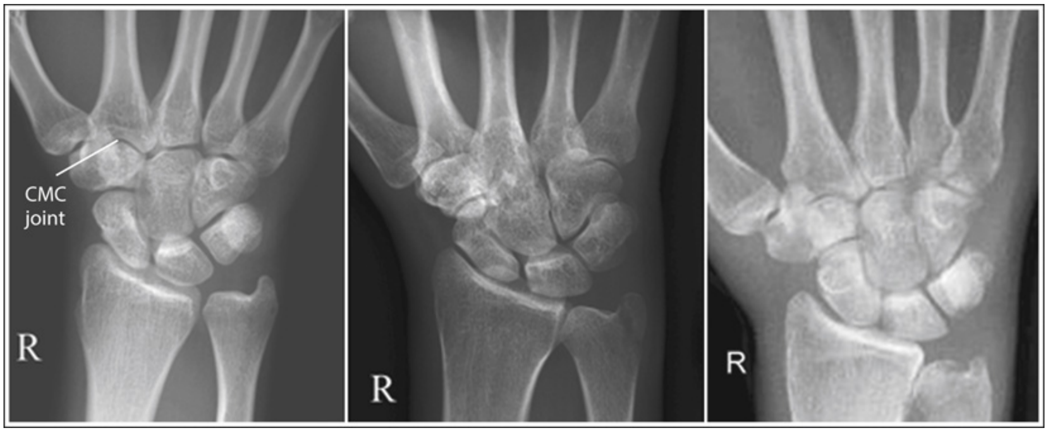


FIGURE 1.4 PA wrist projections demonstrating the difference in carpometacarpal (CMC) joint visualization with variations in metacarpal alignment with the IR.

Terminology

At the beginning of most chapters there is a list of key chapter terms. The glossary at the end of this text provides definitions of these terms.

Characteristics of the Optimal Projection

An optimal image of each projection demonstrates all of the most desired features, as described in **Box 1.1**.

Because of a patient's condition, equipment malfunction, or technologist error, such perfection is not obtained for every projection that is produced. A less than optimal projection is thoroughly evaluated to determine the reason for error so that the problem can be corrected before the examination is repeated. A projection that is not optimal but is still acceptable according to a facility's standards is carefully studied to determine whether skills can be improved before the next similar examination; continuous improvement is sought.

This text cannot begin to identify the variations in the standards of acceptability in all the different imaging facilities. What might be an acceptable standard in one facility may not be what is desired in another. As you study the projections in **Chapters 2** to **11**, you may find that many of them are accepted in your facility even though they do not meet the guidelines as written. You may also find that a guideline that is listed is not desired in your facility. The goal of this text is not to dictate what an acceptable or unacceptable projection is, because that is determined by the needs of the reviewer. The most common radiography positioning and exposure practices were used when deciding the positioning and image analysis guidelines that are listed in the tables for each projection.

Box 1.1 **Characteristics of the Optimal Projection *EI*, Exposure index; *IR*, image receptor; *VOI*, values of interest.**

- Projection is accurately displayed
- Demographic information (e.g., patient and facility name, time, date) is visualized
- Correct marker(s) is in the appropriate position without superimposing the VOI
- Desired anatomic structures are in the exposure field and are in accurate alignment with each other
- There is maximum spatial resolution
- Radiation protection practices were accurately used during the exposure
- Image histogram was accurately produced without errors
- Adequate exposure reached the IR based on ideal EI

- Contrast resolution identifies the subject contrast
- Noise is minimal (including scatter and preventable artifacts)

Image Analysis Process

After a projection is correctly displayed, it is evaluated for positioning and technical accuracy. **Table 1.1** provides a systematic approach that is designed to be used when evaluating projections to ensure that all aspects of the projection are analyzed. Under each item in **Table 1.1** there is a list of questions to explore while evaluating a projection. The discussions in **Chapters 1** through **11** will explore these question areas. The answers to all the questions, taken together, will determine whether the projection is optimal, is acceptable, or needs repeating based on professional or departmental standards.

TABLE 1.1

AEC, Automatic exposure control; *CR*, central ray; *EI*, exposure index; *IR*, image receptor; *L*, left; *OID*, object–image receptor distance; *R*, right; *SID*, source–image receptor distance; *SSD*, source-skin distance; *VOI*, values of interest.

1. Demographic Requirements Are Visualized on the Projection

Projections are evaluated to be certain that the correct patient has been associated with the projections obtained on that patient before they are sent to a picture archival and communication system (PACS). This is accomplished with computed radiography when the cassette's barcode label is scanned and associated with the patient's identification barcode and examination request and with digital radiography (DR) when the patient

and examination order is pulled up on the workstation before the examination is obtained. It is when the projection being obtained is selected from the workstation that the algorithms used to display and rescale the projection are also selected.

Once a projection is sent to the PACS, it is immediately available to whoever has access, and it will make it difficult to retrieve. If the projection is allocated with the wrong patient, the projection may be seen or evaluated by a physician before the misassociation is noticed.

If incorrect patient information is assigned to a projection, the technologist can reassociate the examination to the correct patient as long as the projection has not been sent to the PACS. If the projections are sent to the PACS with the incorrect patient assigned to the examination, the PACS coordinator must be immediately notified to correct the error before the projections are viewed.

2. Projection Is Accurately Displayed on the Workstation Screen

Digital images are displayed on the workstation screen in the manner that they were obtained or after a preprocessing algorithm has been applied that changes how the projection is to be displayed to meet the facilities' desires (e.g., a left lateral chest projection may be transversely flipped to be displayed as a right lateral).

How the patient is oriented on the IR during the procedure determines if a projection will be displayed accurately on the workstation or if it will require postprocessing manipulation. Each digital system's IR has a “top” and “right” or “left” side orientation. These orientation indicators align the image orientation with the computer algorithm of a patient in the anatomic position (AP projection). As long as the top indicator is placed under the

portion of the anatomy that is to be up when the projection is displayed, the projection will be displayed with the correct anatomy at the top. On AP projections where the right and left sides of the patient are included (torso, skull, etc.), the patient's right side is aligned with the right orientation indicator on the IR to accurately display the patient's left side on the viewer's right side. For PA projections, where the patient's left side will be oriented with the right side of the IR during the procedure, the associated algorithm will request that the computer transversely flip the projection obtained before it is displayed. **Table 1.2** lists display guidelines to explore when analyzing the display acceptability.

TABLE 1.2

AP, Anteroposterior; *CR,* central ray; *IR,* image receptor; *L,* left; *PA,* posteroanterior; *PACS,* picture archival and communication system; *R,* right.

The quality of a projection may appear different depending on where it is displayed in the facility. Display station resolution refers to the maximum number of pixels that the screen can demonstrate. To display projections at full resolution, the display screen must be able to display the same number of pixels as those at which the digital system acquired the projection. If the digital system's matrix size is smaller than the display station's matrix size, the values of surrounding pixels are rounded up or down as needed to display the whole projection. The technologist's workstation display screens typically do not demonstrate resolution as high as that of the radiologist's display screens.

3. Correct Marker Is Visualized on Projection and Demonstrates Accurate Placement

Lead markers are used to identify the patient's right and left sides, indicate variations in the standard procedure, or show the amount of time that has elapsed in timed procedures, such as small bowel studies. The markers are constructed of lead so they are radiopaque. Each projection must include a correctly placed marker. **Table 1.3** lists guidelines to follow when marking and evaluating marker accuracy on projections.

FIGURE 1.5 Orientation of CR with IR for proper display.

FIGURE 1.6 Diagonally displayed right lateral wrist projection. When possible, avoid positioning extremities diagonally on the IR. Projections that are not rotated or are incrementally rotated on the workstation display often do not adjust to fill the display monitor. Aligning the long axis of extremities with the longitudinal or transverse axis of the IR will prevent both issues.

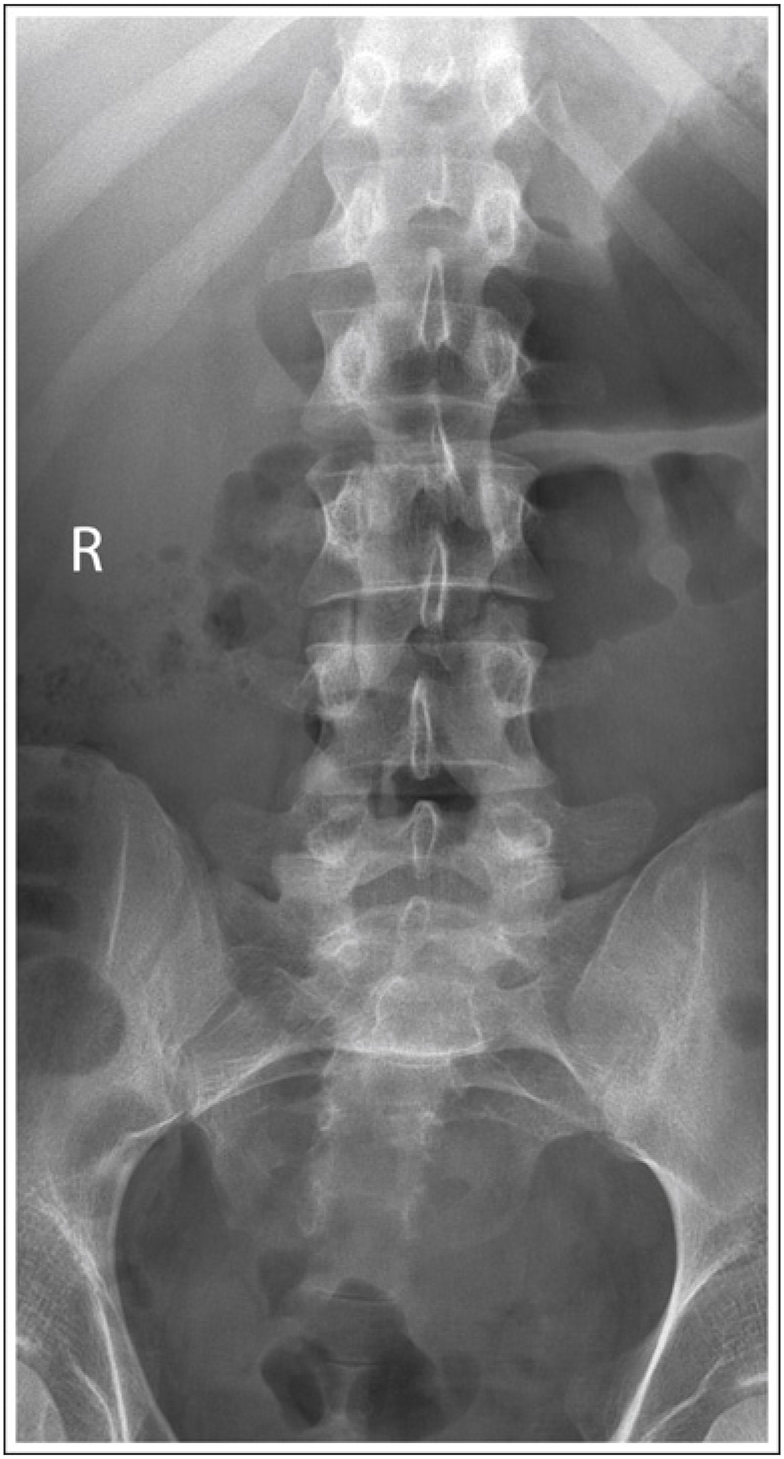


FIGURE 1.7 Accurately displayed and marked AP lumbar vertebrae projection.

FIGURE 1.8 Accurately displayed PA cranium projection.

FIGURE 1.9 Accurately displayed left lateral lumbar vertebrae projection.

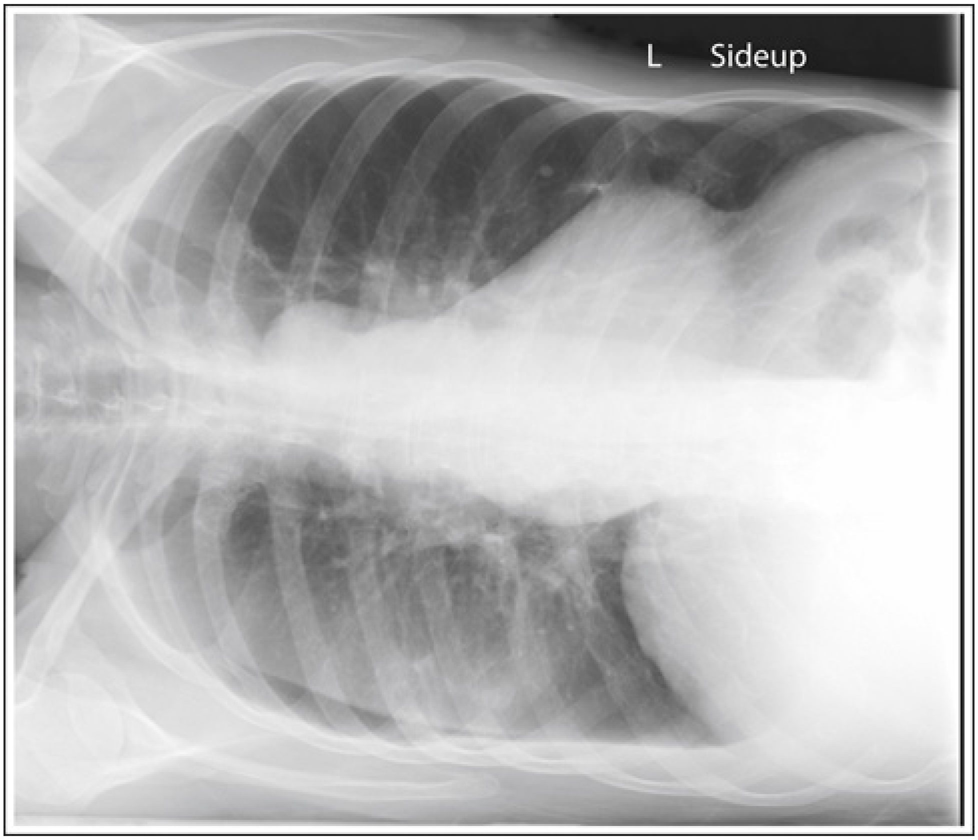


FIGURE 1.10 Accurately displayed and marked AP (right lateral decubitus) chest projection.

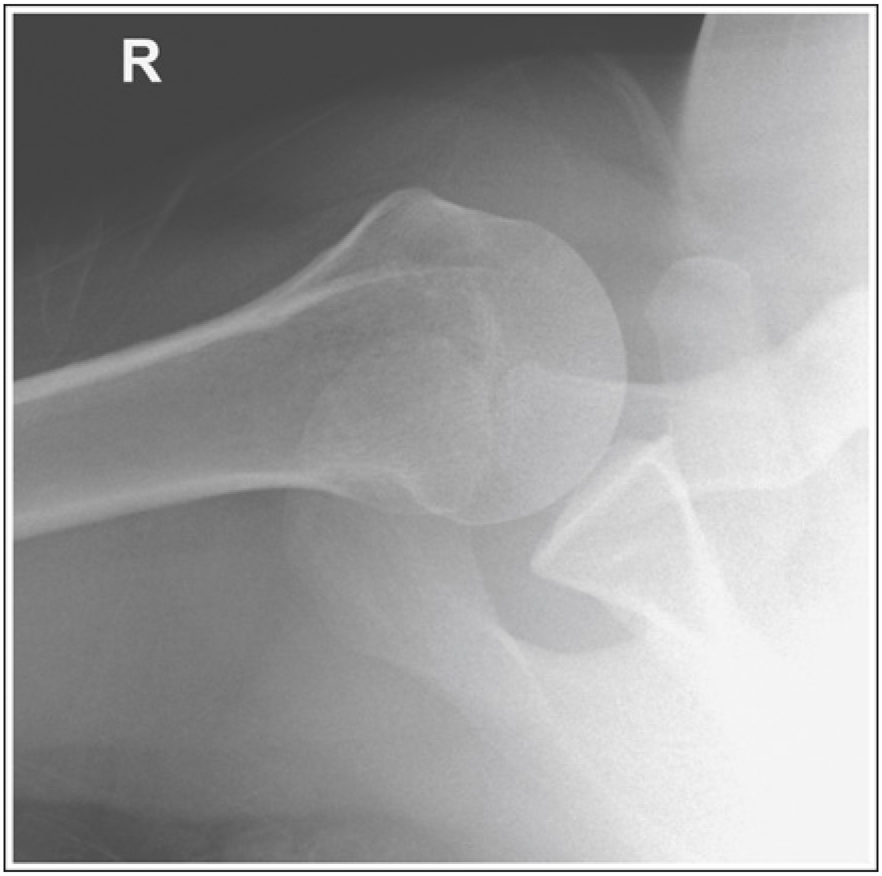


FIGURE 1.11 Accurately displayed and marked inferosuperior (axial) shoulder projection.

FIGURE 1.12 Accurately displayed right PA and lateral hand projections.

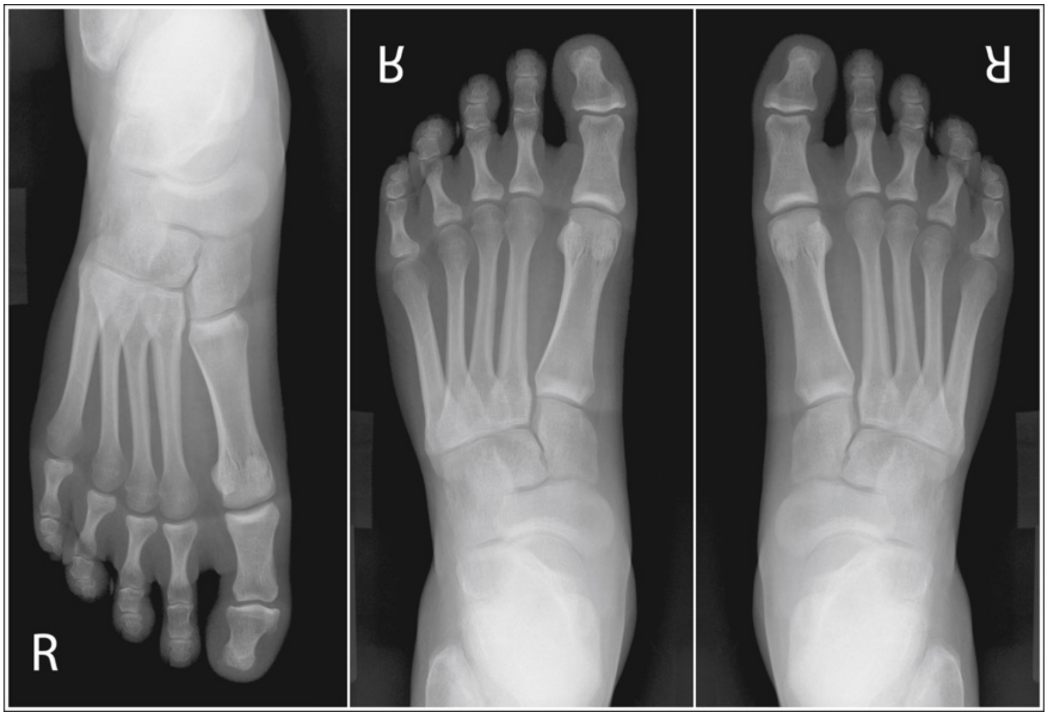


FIGURE 1.13 An AP foot projection that has been displayed upside down, vertically flipped for poor display, and rotated for accurate display. The first AP foot projection was obtained using DR and with the patient seated on the imaging table with the toes pointing toward the foot end of the table. A face-up R marker was placed in the exposure field. Because the patient was not oriented on the IR to have the toes at the top when displayed, the projection was displayed upside down on the workstation monitor. If the projection was vertically flipped to accurately display it, the marker will be reversed and the foot displayed as if it were a left foot instead of a right, as demonstrated in the second foot projection. If the first foot projection was rotated instead of being flipped, the marker will remain face-up and the foot will be

displayed accurately, as demonstrated on the third foot projection.

FIGURE 1.14 Left lateral lumbar vertebrae projection with marker superimposing VOI.

FIGURE 1.15 Markers that have been magnified, distorted, and undercut with scatter radiation.

FIGURE 1.16 Marker placement for lateral lumbar vertebrae projection.

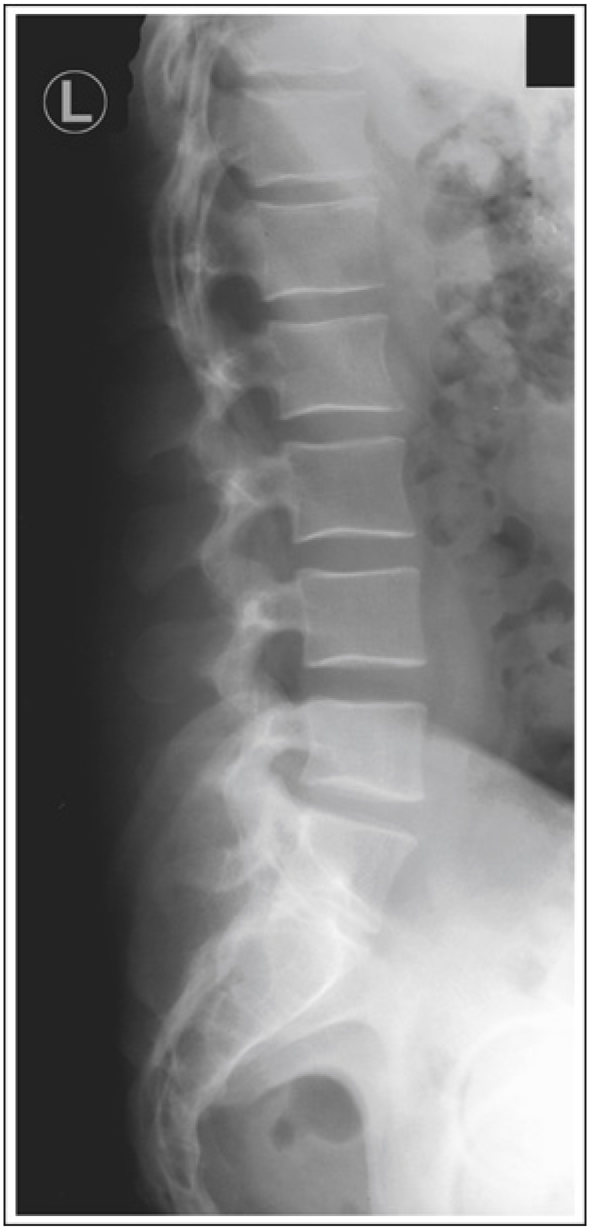


FIGURE 1.17 Markers placed posteriorly on lateral torso or vertebrae projections often have to be annotated because they are obscured by scatter.

FIGURE 1.18 Marker placement for AP oblique lumbar vertebrae projection.

TABLE 1.3

AP, Anteroposterior; *IR*, image receptor; *L*, left; *PA*, posteroanterior; *R*, right; *VOI*, values of interest.

4. Appropriate Collimation Practices Are Evident

Good collimation practices:

- Clearly delineate the values of interest (VOI).
- Decrease radiation dosage by limiting the amount of patient tissue exposed.
- Improve the visibility of recorded details by reducing the amount of scatter radiation that is produced.
- Reduce histogram analysis errors.

Each projection requires that the CR be centered to a particular location and that it is collimated to a particular VOI. For example, all wrist projections require that one-fourth of the distal forearm be included because radiating wrist pain may be a result of a distal forearm fracture, and a lateral ankle projection includes 1 inch (2.5 cm) of the fifth metatarsal base to rule out a Jones fracture. For each projection presented in **Chapters 3** to **11** there are guidelines on what makes up the VOI on the projection and a description of how to collimate to include the VOI (**Table 1.4**).

5. Relationships Between the Anatomic Structures Are Accurate for the Projection Demonstrated

Each projection is to demonstrate specific bony relationships that will best facilitate diagnosis as defined in the procedural analysis sections of this text. Most positioning routines require AP-PA and lateral projections to be taken to demonstrate superimposed anatomic structures, localize lesions or foreign bodies (**Fig. 1.37**), and determine alignment of fractures (**Fig. 1.38**). When joints are of interest, oblique projections are also added to this routine to visualize obscured areas better. In addition to these, special

projections may be requested for more precise demonstration of specific anatomic structures and pathologic conditions.

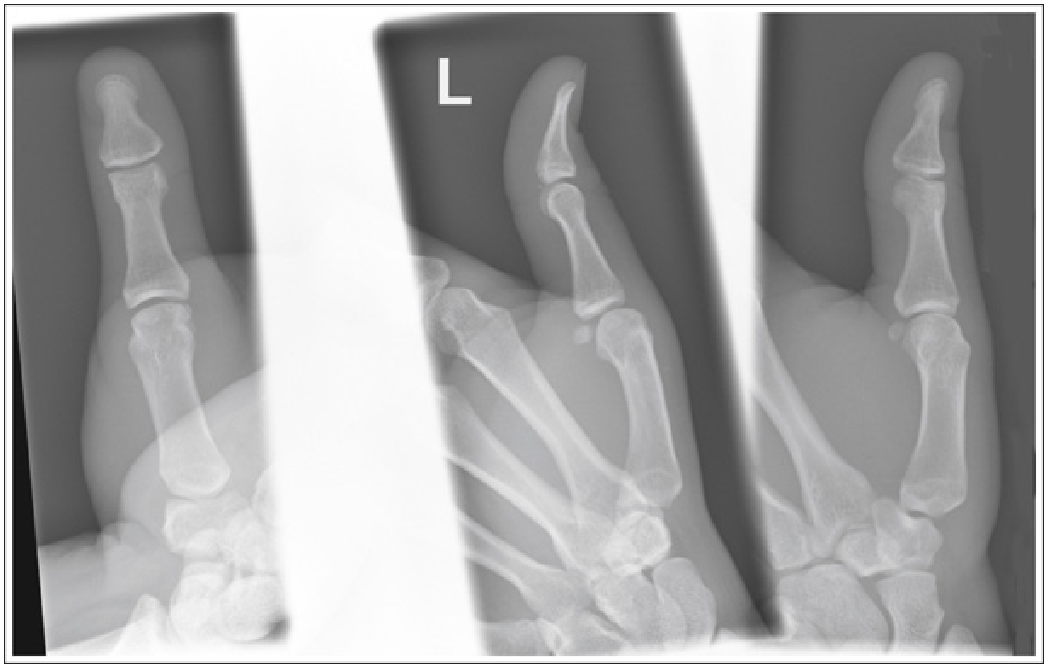


FIGURE 1.19 Marker placement for unilateral finger projections on one IR.

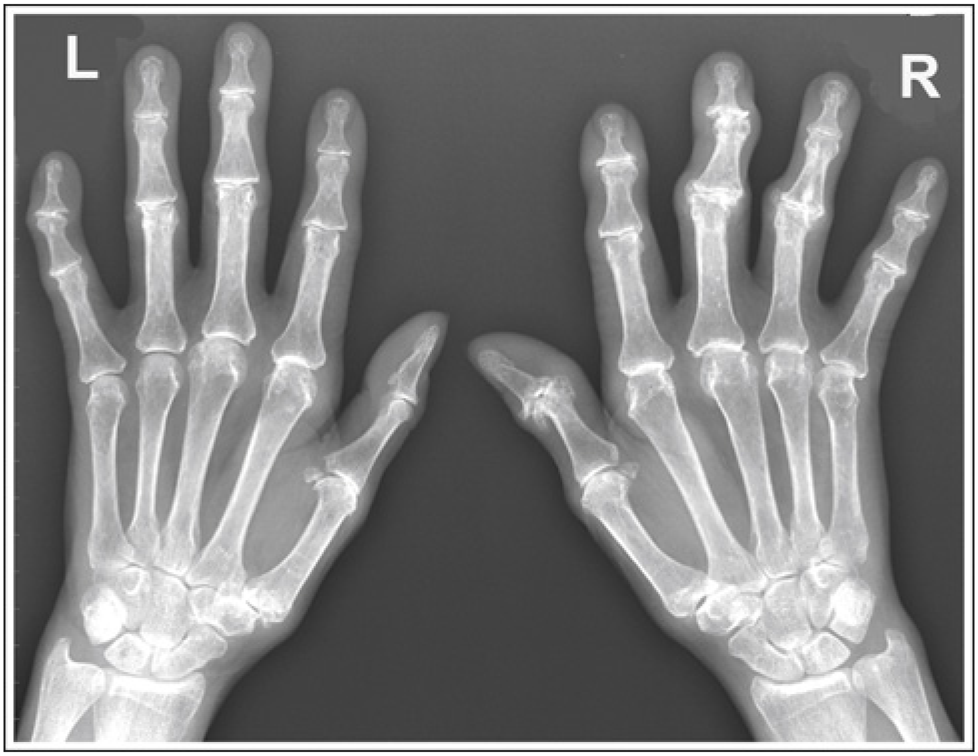


FIGURE 1.20 Marker placement for bilateral PA hand projections.

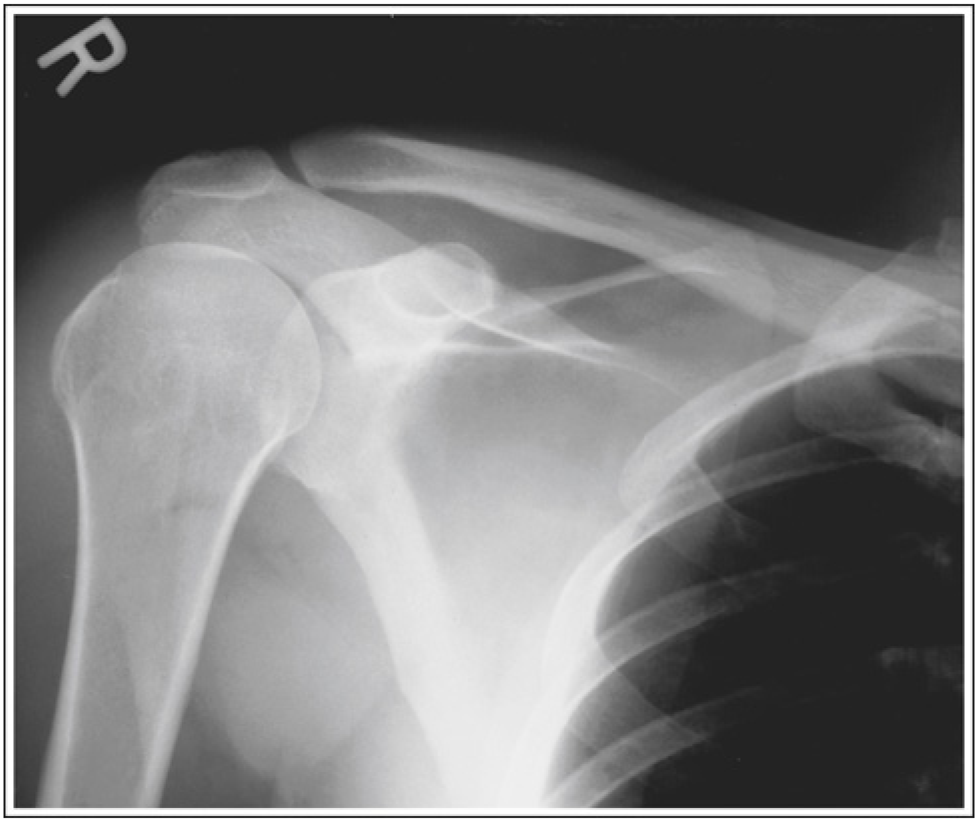


FIGURE 1.21 Marker placement for an AP projection of shoulder.

FIGURE 1.22 Poor marker placement on an AP projection of hip.

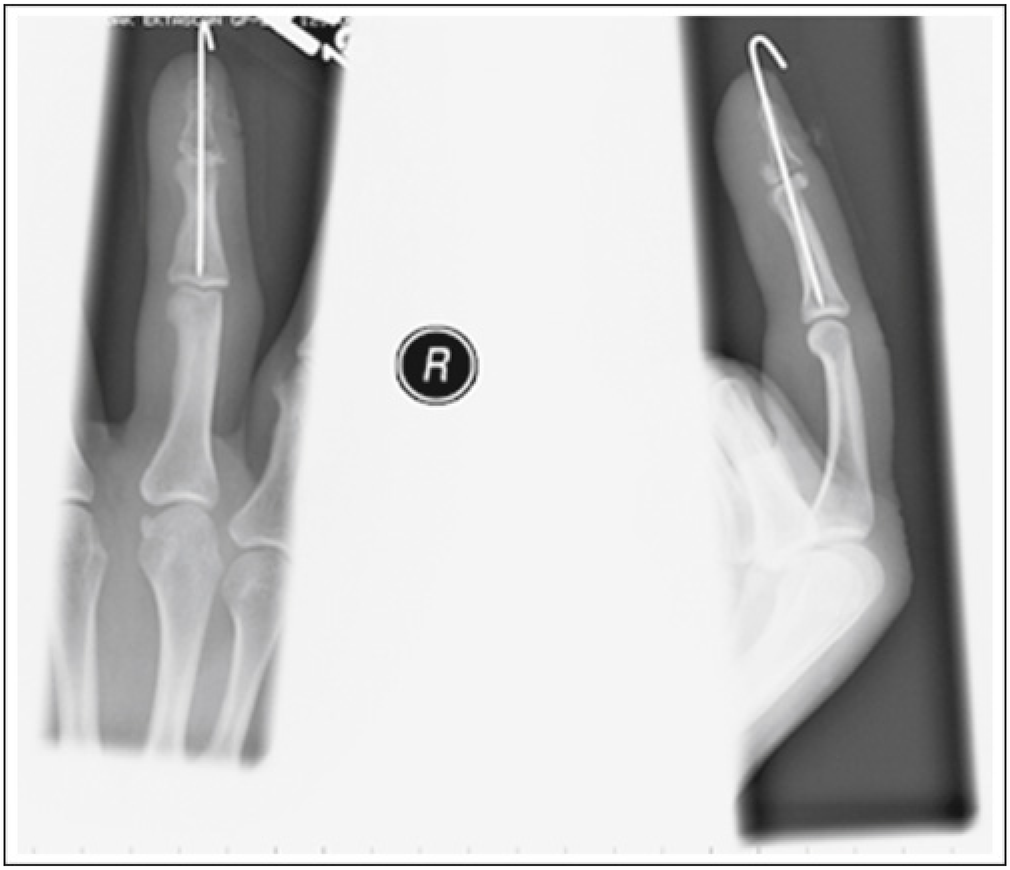


FIGURE 1.23 Partially visible marker and annotation.

FIGURE 1.24 Proper “to skin line” collimation on an AP forearm projection.

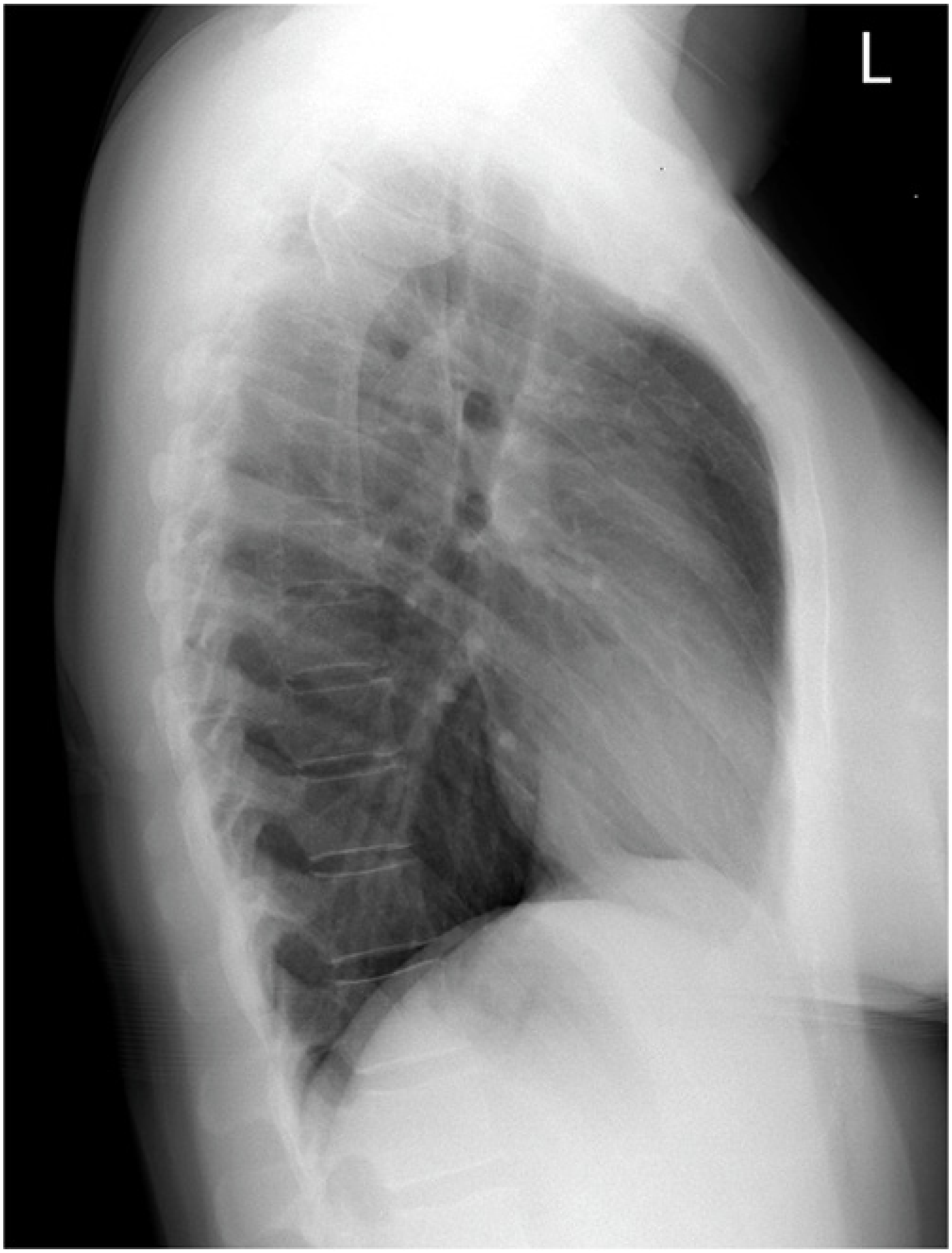


FIGURE 1.25 Proper “to skin line” collimation on a lateral chest projection.

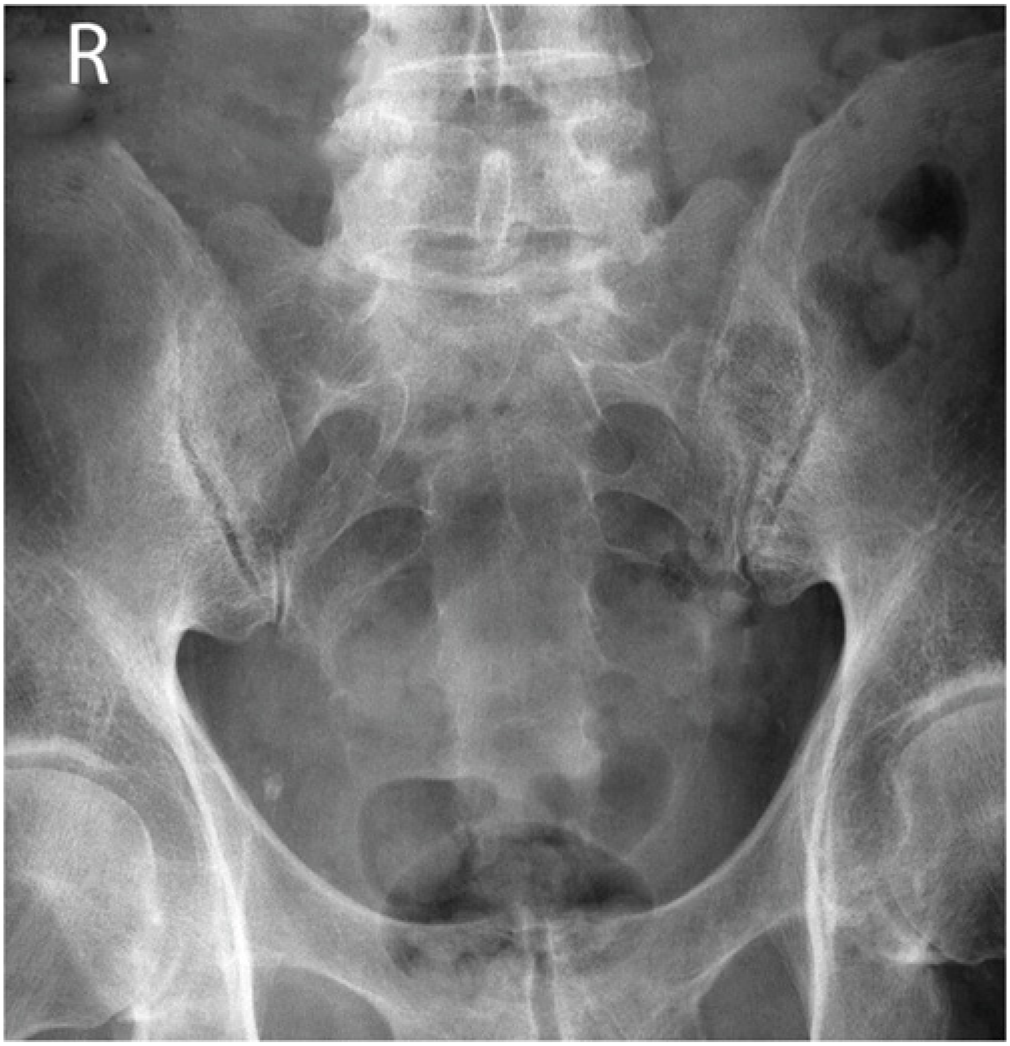


FIGURE 1.26 Proper collimation on an AP sacral projection.

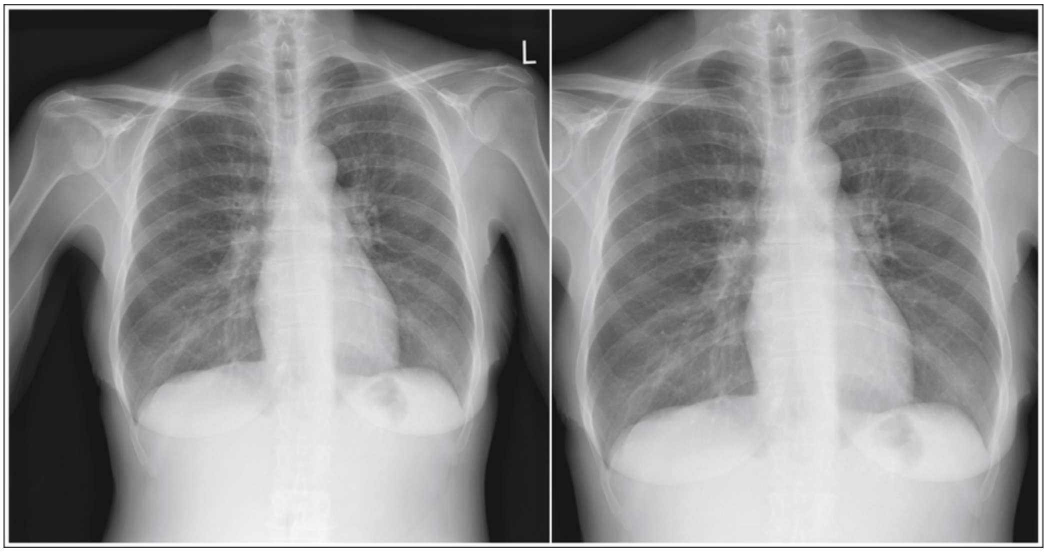


FIGURE 1.27 Collimation determines how the VOI will fill the workstation screen. The first AP chest projection was obtained with less collimation than the second. Note how collimation determines how the display screen will be filled.

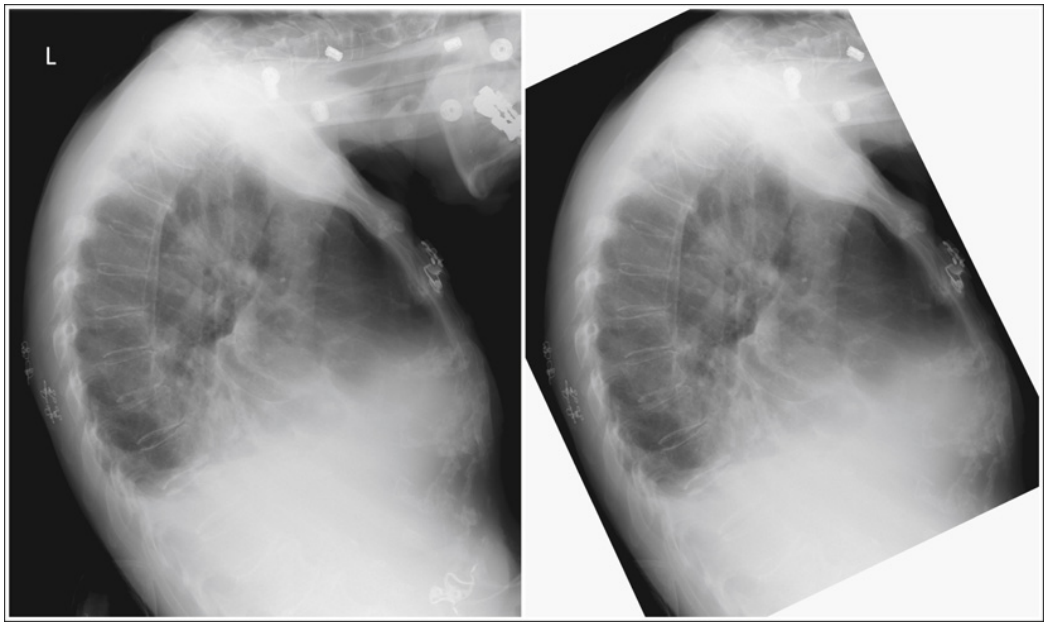


FIGURE 1.28 Nonrotated and rotated collimator head on tilted lateral chest projection to obtain tighter collimation.

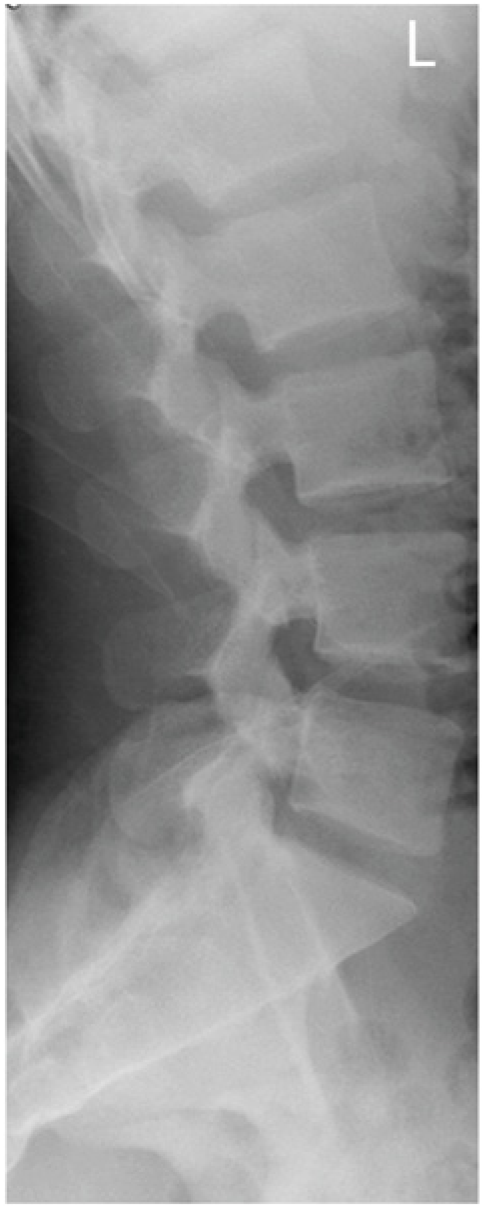


FIGURE 1.29 Overcollimation on a lateral lumbar vertebral projection.

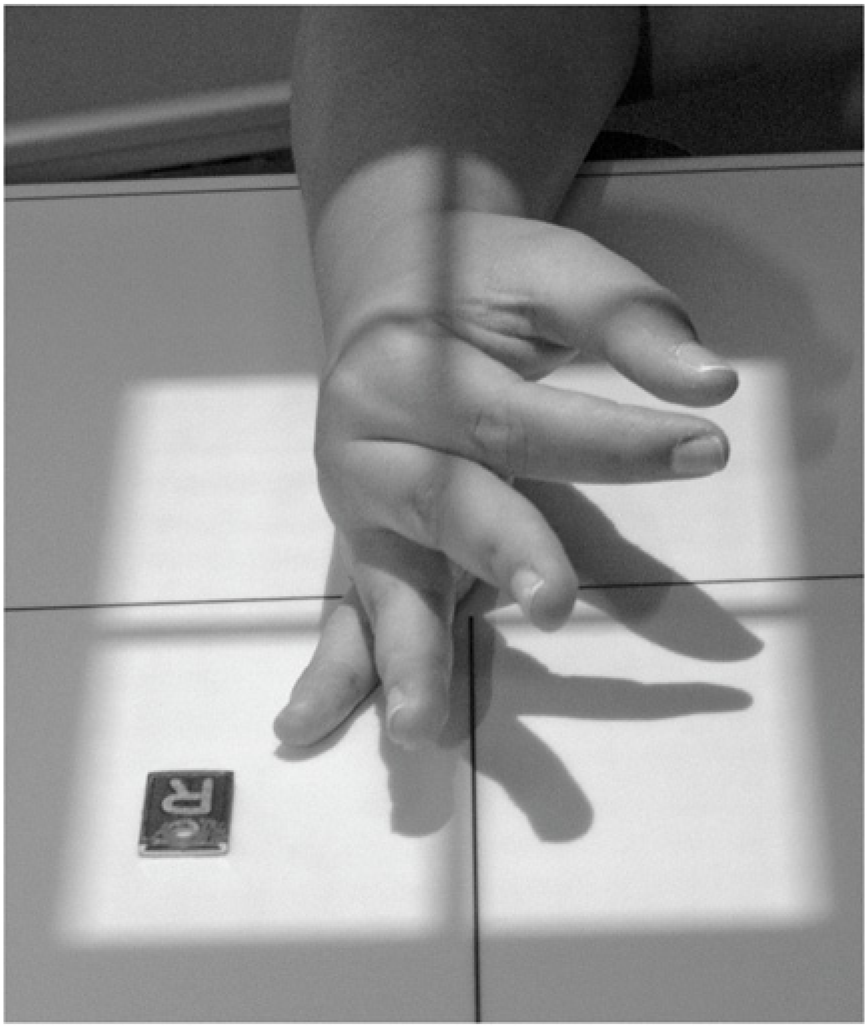


FIGURE 1.30 View the shadow the patient creates on the IR to determine proper collimation. Magnification of the part is represented by the shadow. Clipping the shadow will mean clipping this area of the part on the resulting image.

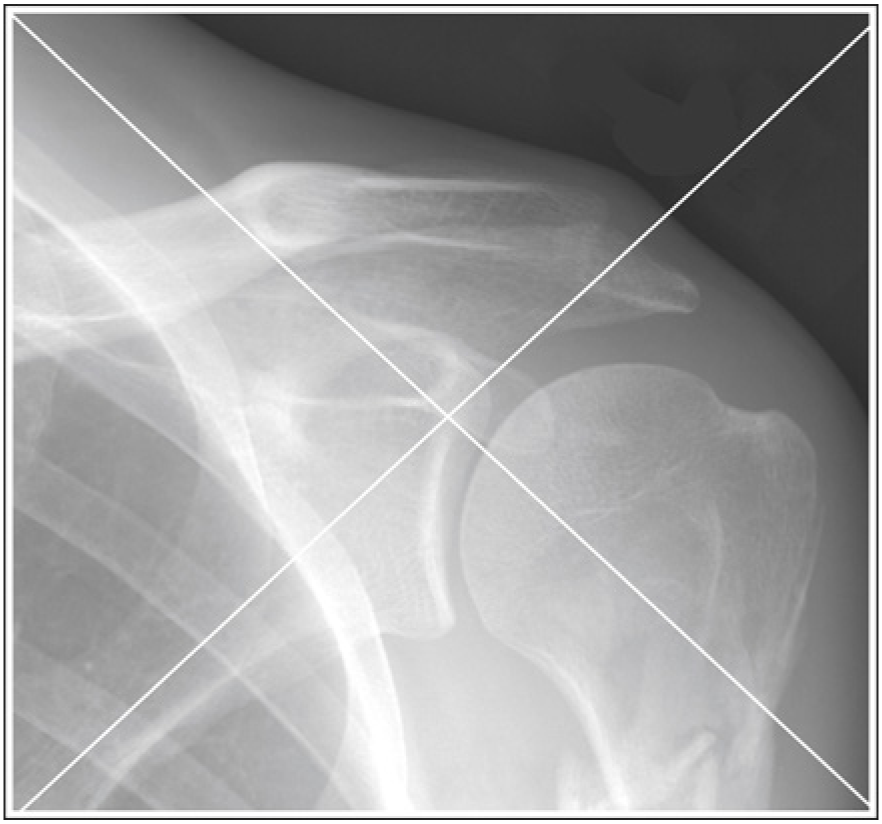


FIGURE 1.31 Using collimated borders to locate CR placement.

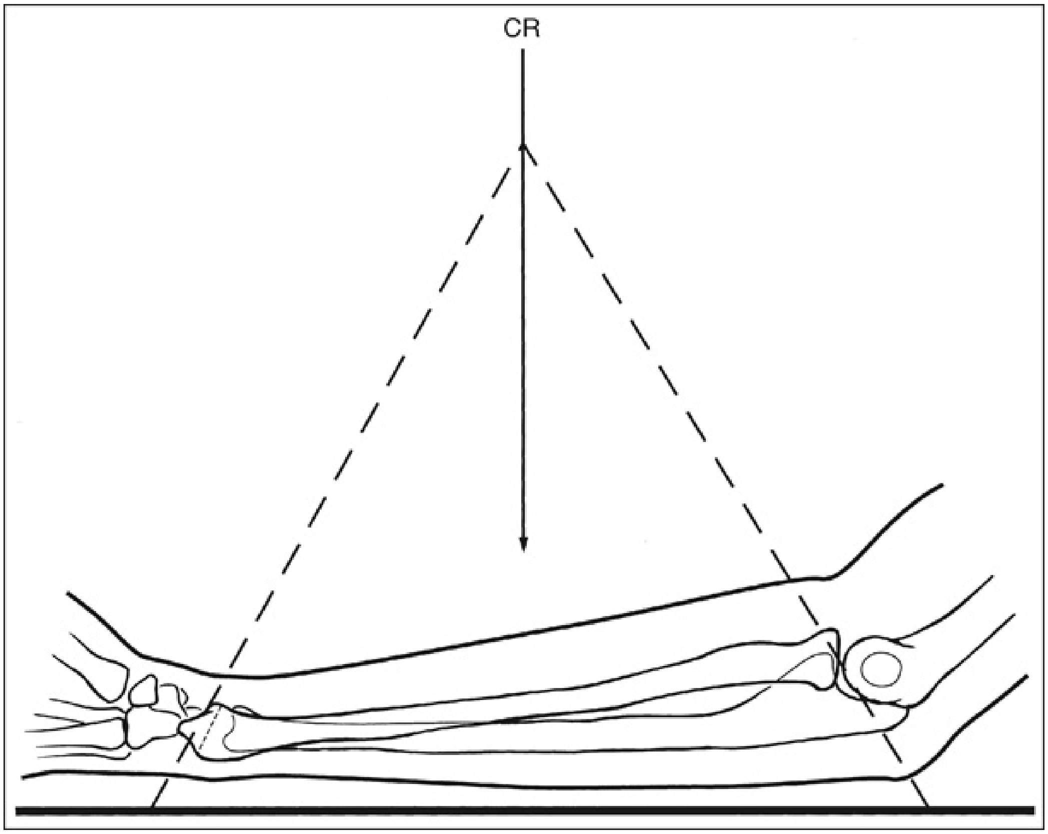


FIGURE 1.32 Proper positioning of long bones with diverged x-ray beam.

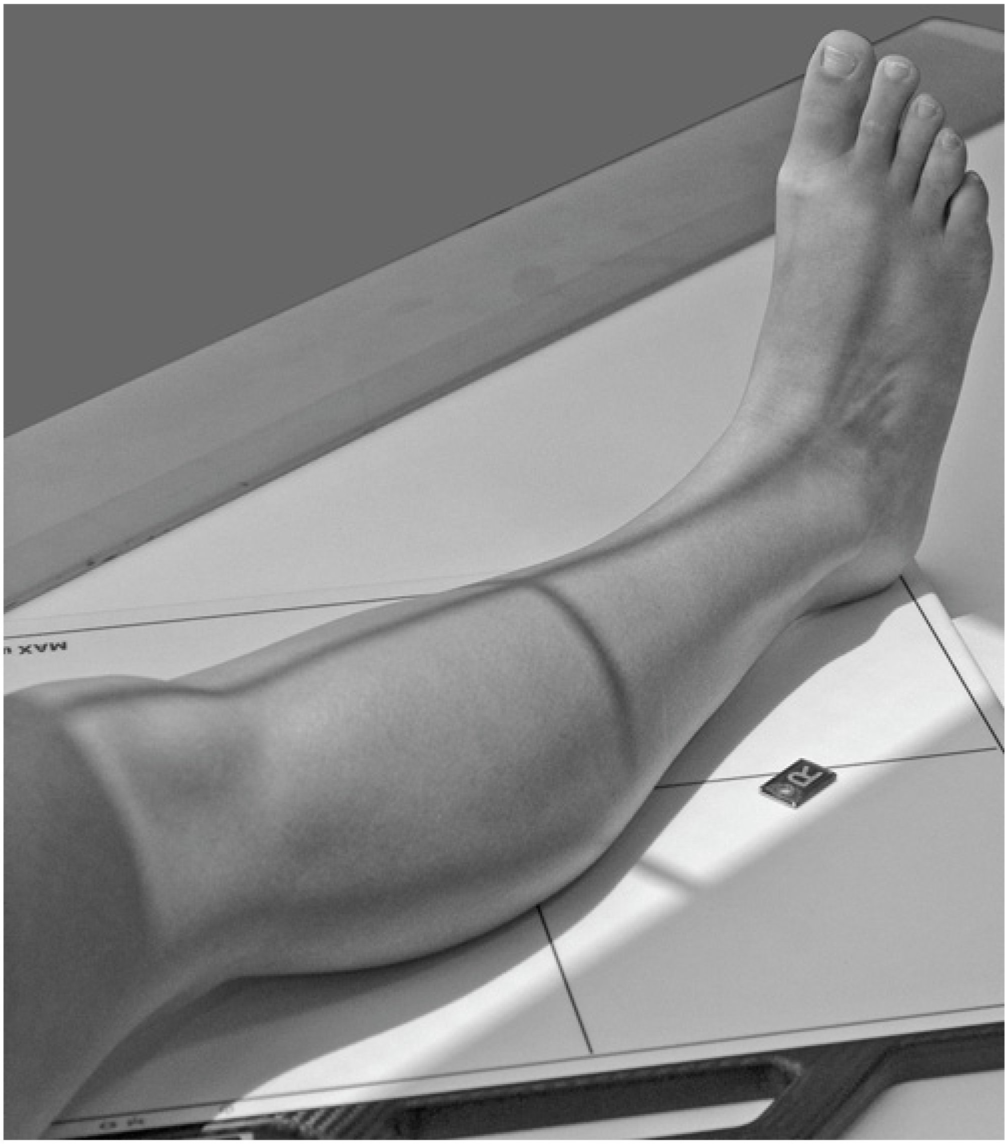


FIGURE 1.33 Diagonally positioning long bones on the IR to include both joints.

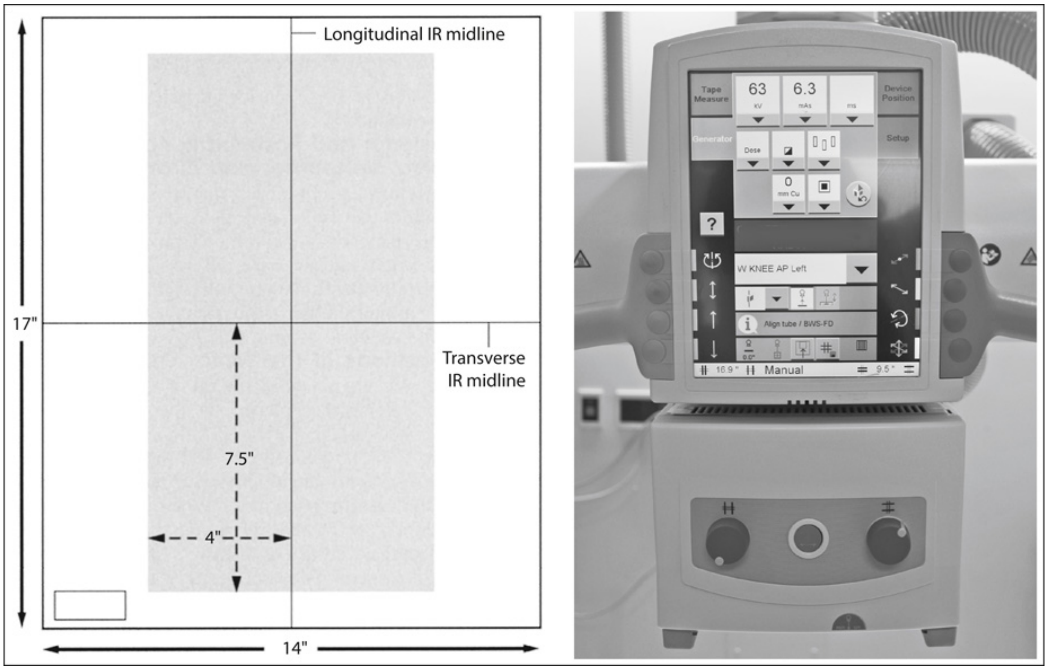


FIGURE 1.34 Marker placement for tightly collimated image.

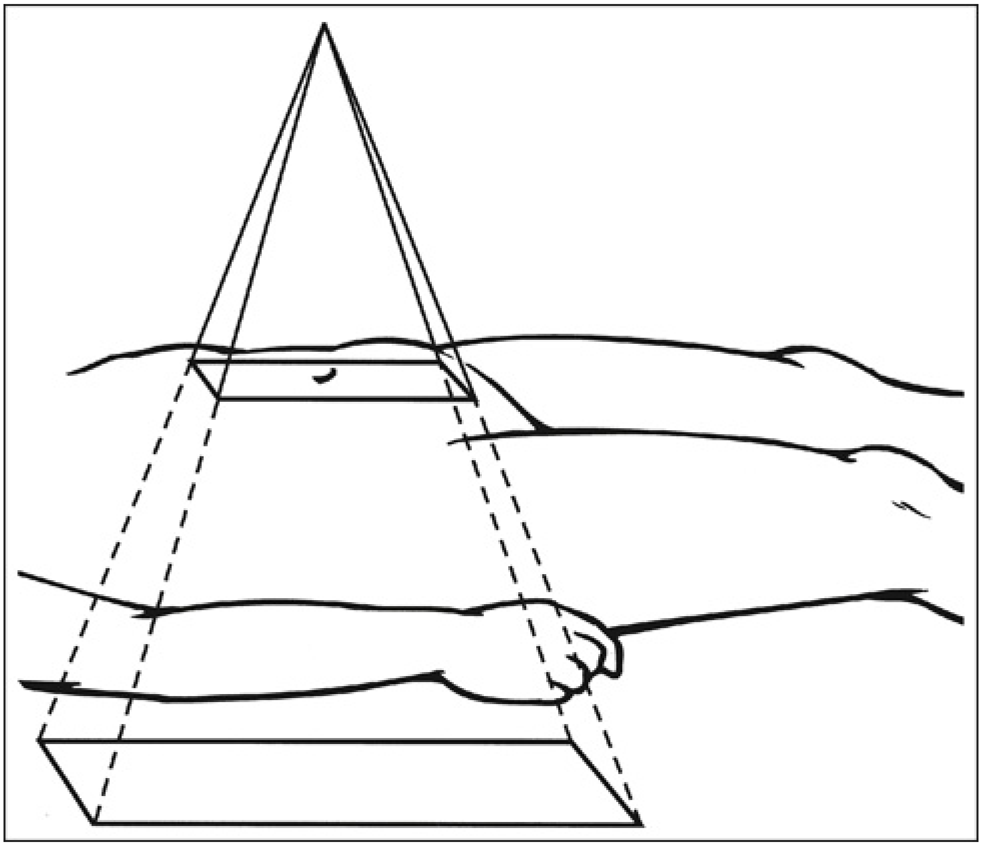


FIGURE 1.35 Collimator light field versus IR coverage.

TABLE 1.4

CR, Central ray; *IR*, image receptor; *OID*, object–image receptor distance; *PACS*, picture archival and communication system; *VOI*, values of interest.

To appreciate the importance of the anatomic relationships on a projection, one must understand the clinical reason for what the procedure is to demonstrate for the reviewer. An optimally positioned tangential (supraspinatus outlet) shoulder projection (**Fig. 1.39**) demonstrates the supraspinatus outlet (opening formed between acromion and humeral head) and the posterior aspects of the acromion and acromioclavicular (AC) joint in profile. The technologist produces these anatomic relationships when the

midcoronal plane is positioned vertically and it can be ensured that the proper positioning was obtained when the superior scapular angle is positioned at the level of the coracoid tip on the projection. From this optimal projection the radiologist can evaluate the supraspinatus outlet for narrowing caused by variations in the shape (spur) or slope of the acromion or AC joint, which has been found to be the primary cause of shoulder impingements and rotator cuff tears. If instead of being vertical, the upper midcoronal plane was tilted toward the IR, the resulting projection would demonstrate the superior scapular angle positioned above the coracoid tip, preventing clear visualization of the acromion and AC joint deformities, because their posterior surfaces would no longer be in profile and would narrow or close the supraspinatus outlet (**Fig. 1.40**). Because the reviewer would be unable to diagnose outlet narrowing that results from variations in the shape or slope of the acromion or AC joint, this projection would not be of diagnostic value.

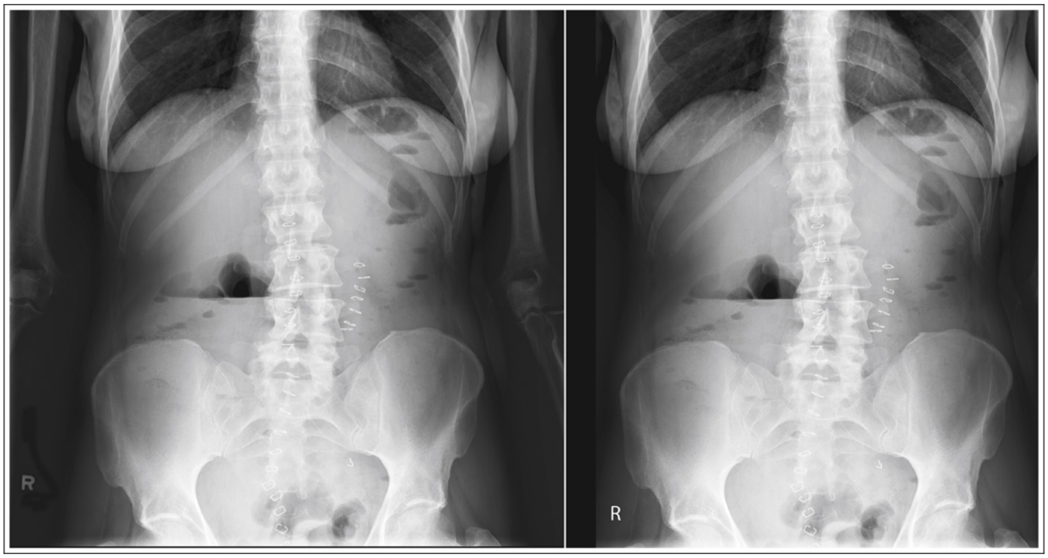


FIGURE 1.36 AP abdomen projections with and without contrast masking. The first projection shows that the arms were included along the sides of the torso. The second projection has the contrast mask exceeding into the exposure field, excluding the humeri and hiding the arms that were included in the exposure. Because the second projection was equally masked on both sides, the perceived placement of the CR is the same as the original projection. If the contrast mask exceeded into the exposure field on only one side, the perceived location of the CR placement will move in the same direction.

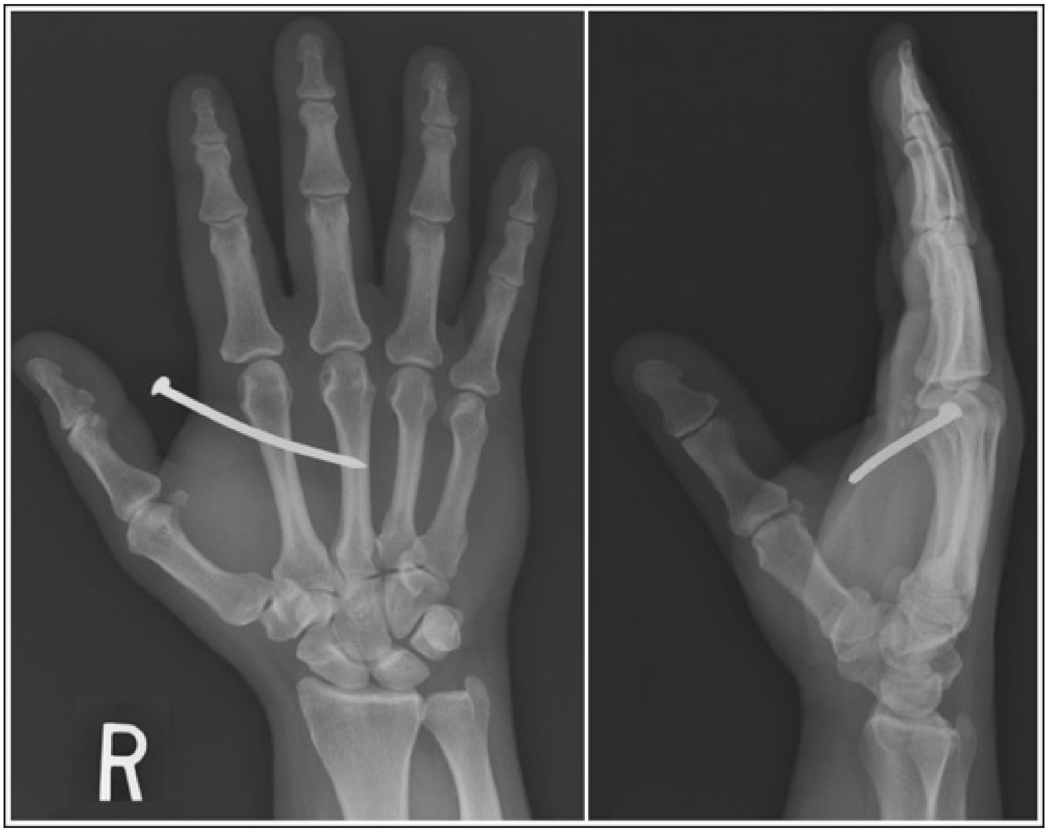


FIGURE 1.37 PA and lateral hand projections to identify location of foreign body (nail).

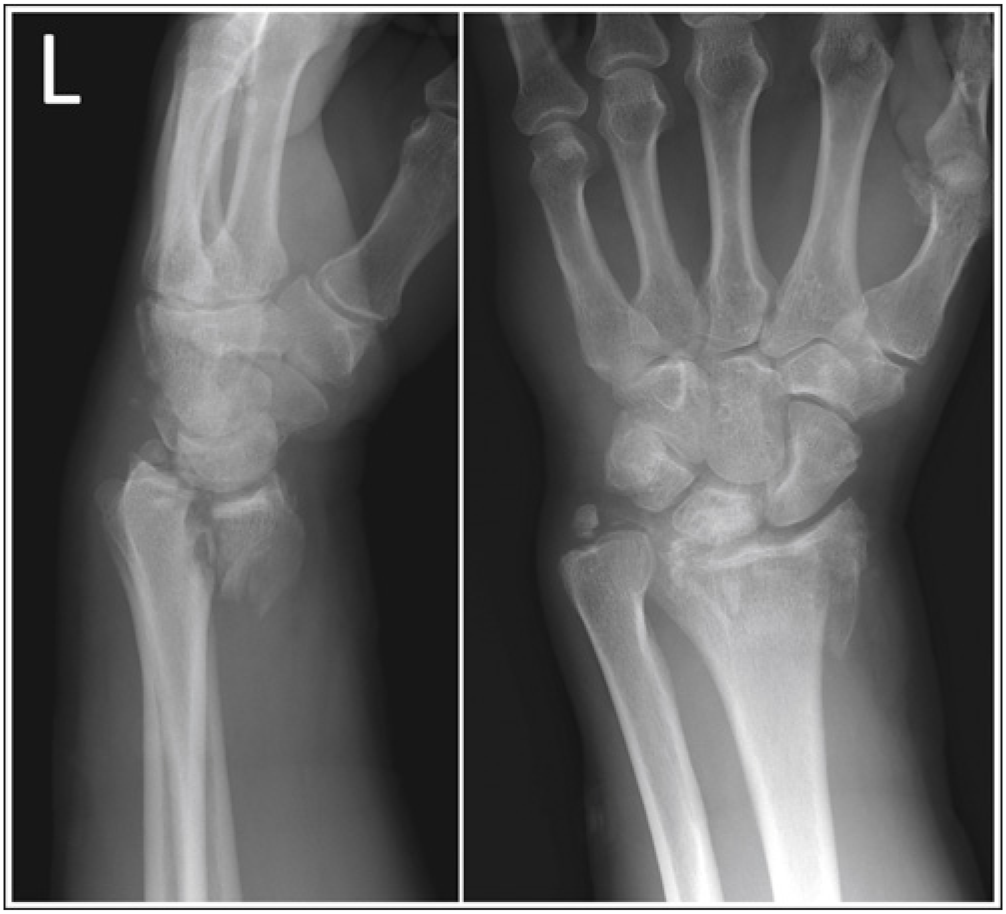


FIGURE 1.38 Lateral and PA wrist projection to demonstrate distal forearm fracture alignment.

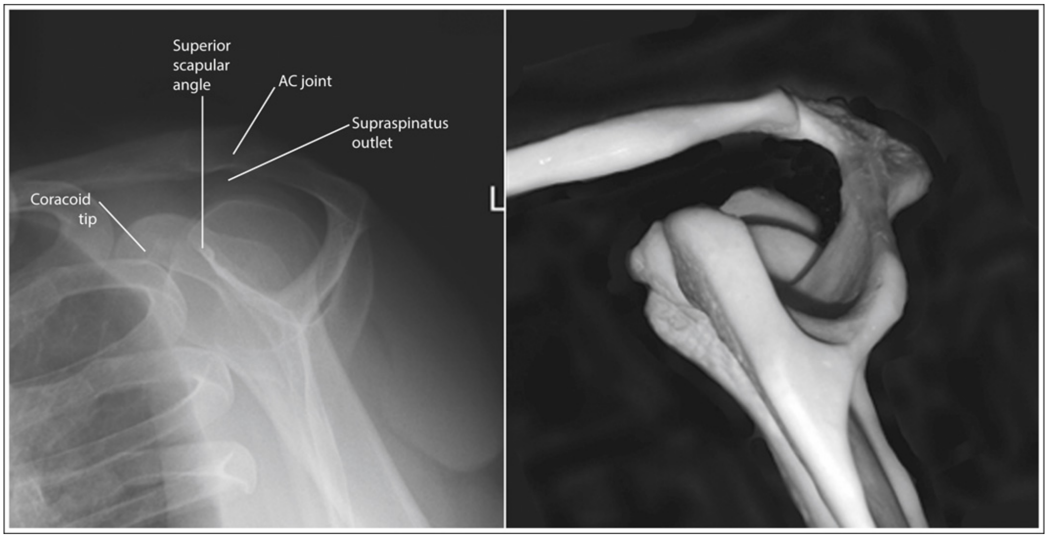


FIGURE 1.39 Properly positioned skeletal bones and shoulder in the tangential (supraspinatus outlet) projection.

FIGURE 1.40 Poorly positioned tangential (supraspinatus outlet) shoulder projection.

For each projection in the procedural analysis sections of this book, there is a list of:

- Image analysis guidelines to use when evaluating the anatomic relationships that are seen on an optimal projection
- An explanation that correlates the anatomic relationships with the specific positioning procedure(s)
- A description, with correlating projections, of related positioning errors to use to properly reposition the patient if an unacceptable projection is obtained and needs repeating

An optimal projection appears as much like the real object as possible, but because of unavoidable distortion that results from the shape, thickness,

and position of the object and beam, part, and IR alignment, this is not always feasible, resulting in some anatomic structures appearing different from the real object. Using skeletal bones positioned in the same manner as the projection will greatly aid in identification of the anatomic structures on a projection. Closely compare the visualization of the anatomic structures on the skeletal scapular bone photograph and tangential shoulder projection shown in **Fig. 1.39**. Note that the superior scapular angle and lateral borders of this surface on the skeletal image are well demonstrated, obscuring the coracoid, but on the tangential projection the superior scapular angle is seen as a thin cortical line, its lateral borders are not demonstrated, and the coracoid can be clearly visualized. Also note that the superior surface of the spine is visualized on the skeletal bone image between the lateral and medial scapular spine borders but is not seen on the x-ray projection.

When identifying anatomic structures, one must consider how anatomy may appear different from the real object. **Table 1.5** lists imaging concepts and guidelines that, when understood and applied to how the procedure was obtained, can help with identification of the anatomic structures on the projection.

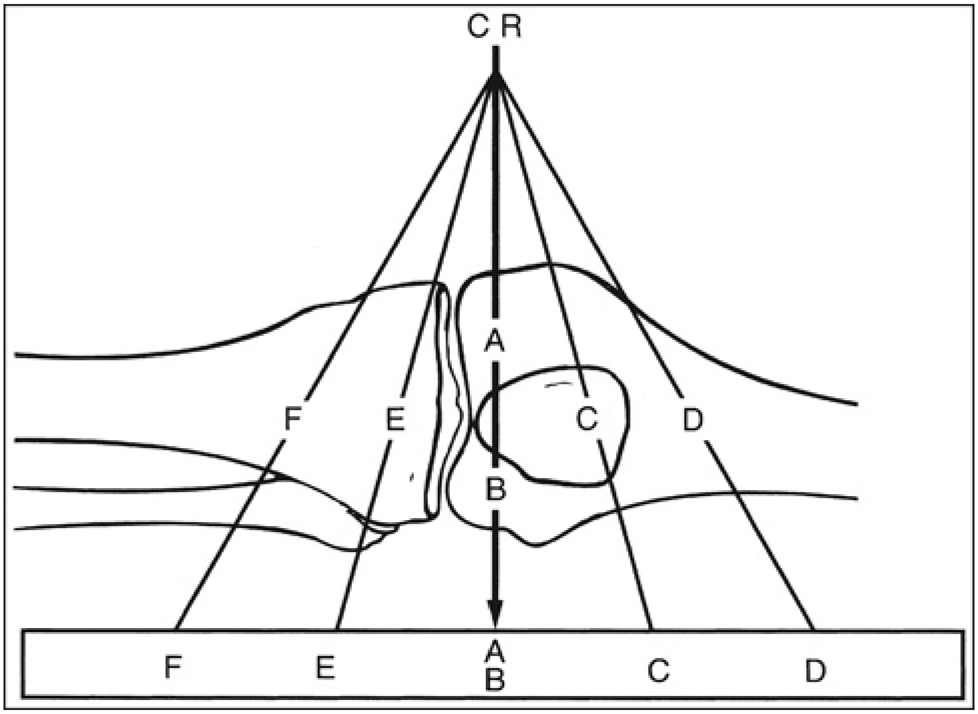


FIGURE 1.41 Effect of CR placement on anatomic alignment.

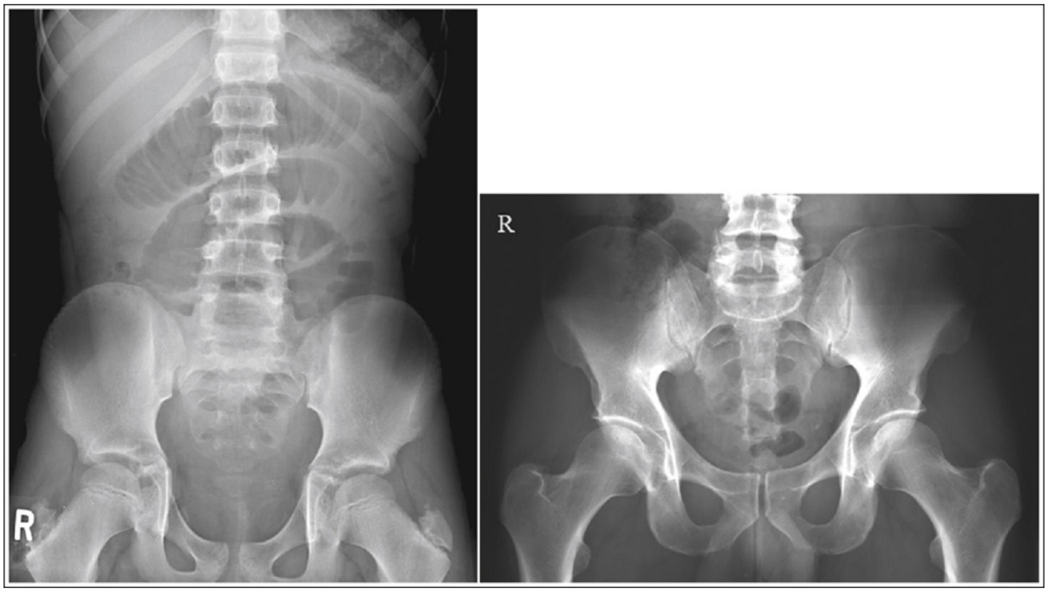


FIGURE 1.42 Properly positioned AP abdomen and pelvis projections demonstrating the effect of CR placement. Compare the relationship of the pubis symphysis and coccyx and how differently the sacrum is visualized. Both projections are taken with a perpendicular CR, but the CR is centered to the midsagittal plane at the level of the iliac crest for the abdomen projection and is centered at the inferior sacrum for the pelvis projection. The pubis symphysis and coccyx on both projections were recorded using diverged beams, but because the CR is centered more superiorly and beams with greater angles of divergence were used to record the pubis symphysis and coccyx on the abdomen projection, the pubis symphysis is moved more inferiorly to the coccyx on this projection when compared with its alignment with the coccyx on the pelvis projection. Also compare sacral visualization on these two projections. Because

of the more inferior centering used in the pelvis projection, the x-rays recording the sacrum are angled cephalically into the curve of the sacrum and those recording the sacrum for the abdomen projection are angled caudally, against the sacral curve. This results in decreased sacral foreshortening on the pelvis projection and increased sacral foreshortening on the abdomen projection. The off-centered diverged beams will affect structures in the same manner that an angled CR will.

FIGURE 1.43 Bilateral projections. It is not uncommon for bilateral projections of the hands, feet, or knees to be ordered for a comparison diagnosis. This off-centering of the CR between the hands results in posteriorly diverged x-rays recording the MCs, which caused the second through fourth MC to be projected posterior to the fifth MC on the hands, producing less than optimal lateral hands because the MCs should be superimposed on lateral hand projections, and they are not on these projections. The farther apart the hands are positioned from each other, the greater will be the amount of lateral divergence and the more supinated the hands will appear. This

appearance can be offset by estimating the degree of x-ray divergence (2 degrees for every 1 inch of off-center) and increasing the degree of internal rotation of the hands from the standard positioning by the same degree.

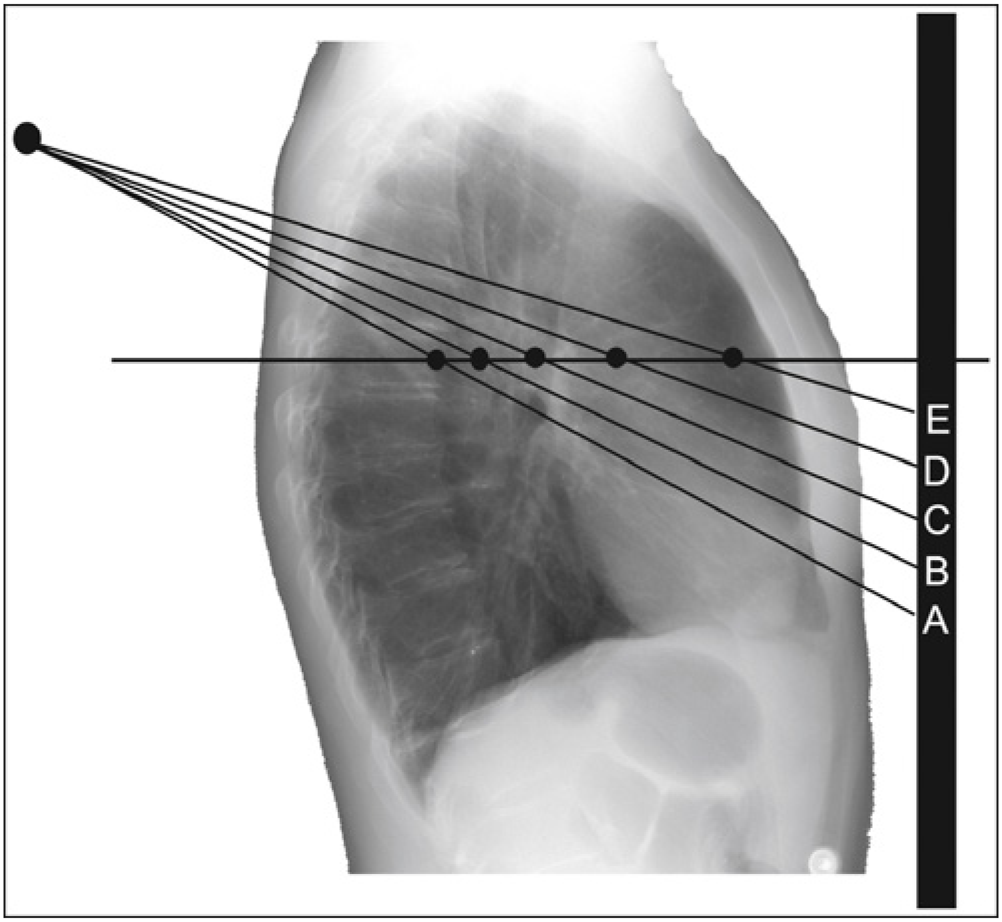


FIGURE 1.44 Using an angled beam. When an angled CR or diverged beam is used to record an object, the object will move in the direction in which the beams are traveling. The more the CR is angled, the more the object will move. Also, note that objects positioned on the same plane but at different distances from the IR, which would have been superimposed if a perpendicular CR were used, will be moved different amounts. In the figure, point A is farther away from the IR than point C, and even though these two points are horizontally aligned, if a caudally angled CR were used to record these two structures, point A would project farther inferiorly than point C on the resulting

projection. If the two structures were closer together (points A and B), the amount of separation between the structures when an angled CR is used would be less, and if the two structures were farther apart (points A and E), the separation between the structures on the resulting projection would be greater.

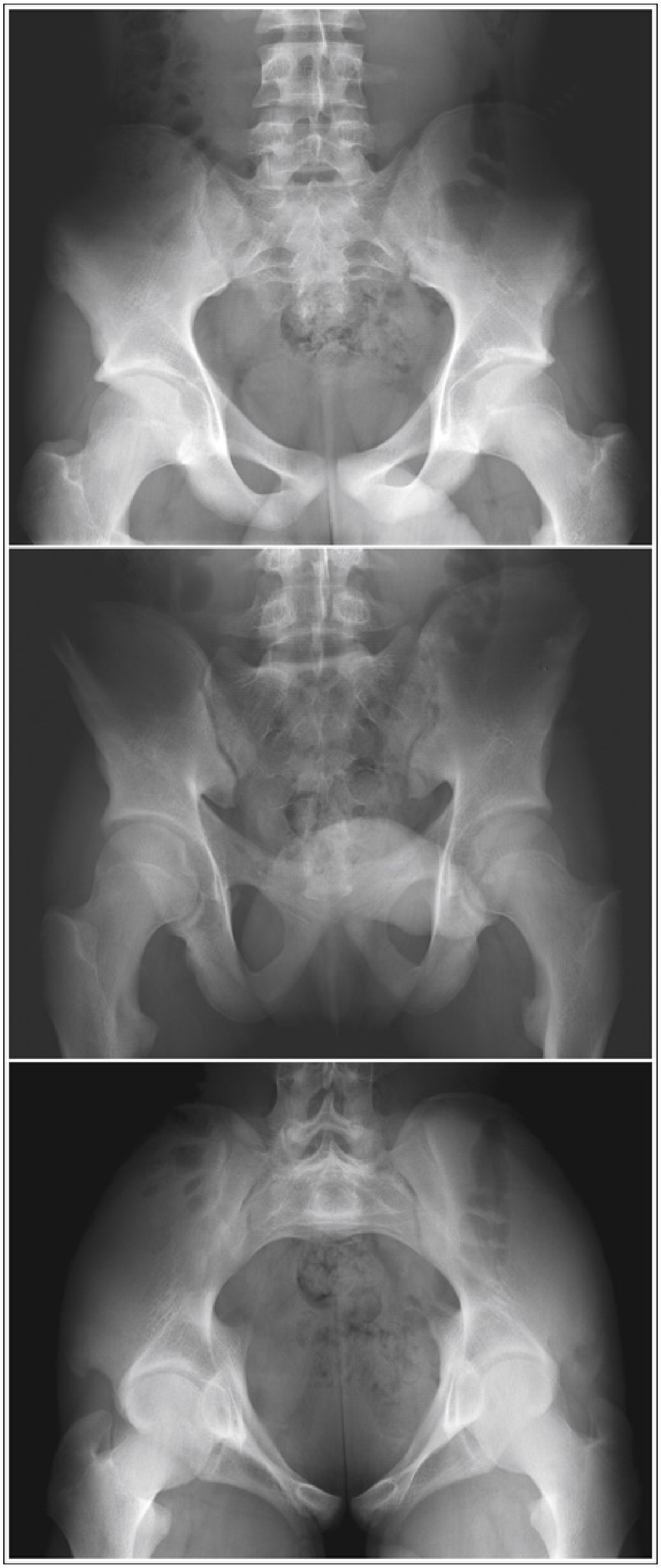


FIGURE 1.45 AP pelvis projections demonstrating the effect of CR angulation: CR perpendicular *(top)*, CR angled cephalically *(center)*, and CR angled caudally *(bottom)*. Note how the structures situated farther from the IR (ASISs, pubis symphysis, and obturator foramen) have moved the direction that the CR was angled and how the same anatomic structures demonstrate different distortion.

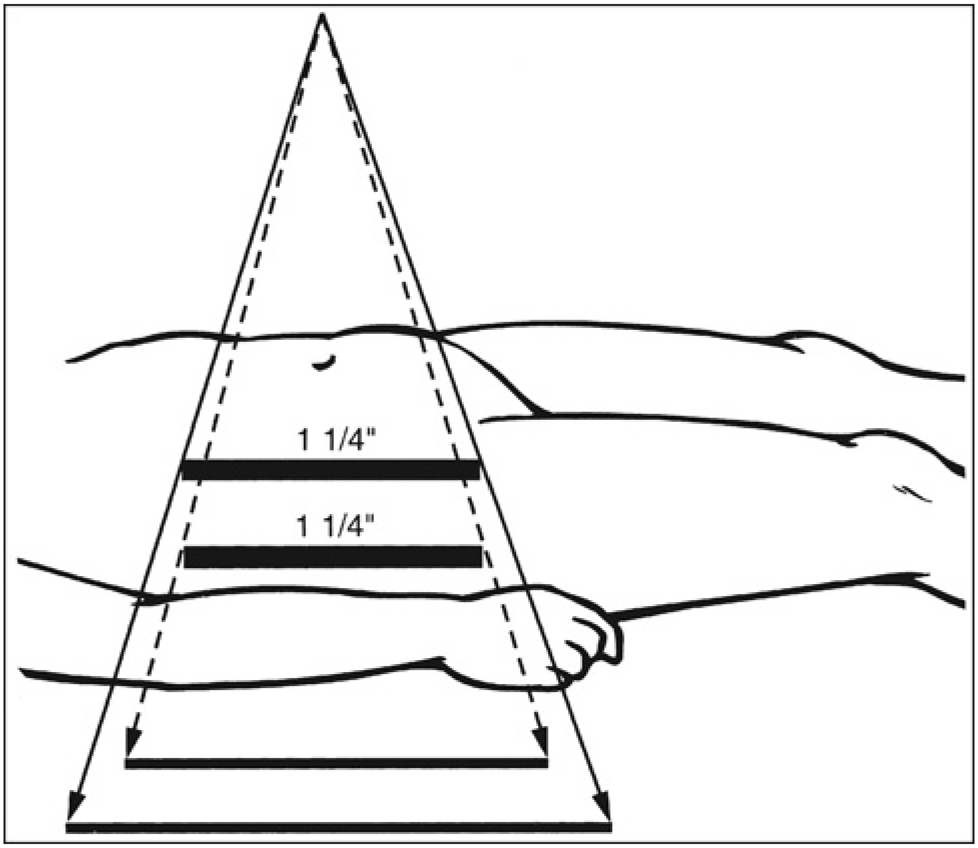


FIGURE 1.46 The part farthest from the IR will be magnified the most. The amount of magnification demonstrated on a projection is dependent on how far each structure is from the IR at a set source–image receptor distance (SID). The farther away the part is situated from the IR, the more magnified the structure will be. Magnification also results when the same structure, situated at the same OID, is imaged at a different SID, with the longer SID resulting in the least magnification.

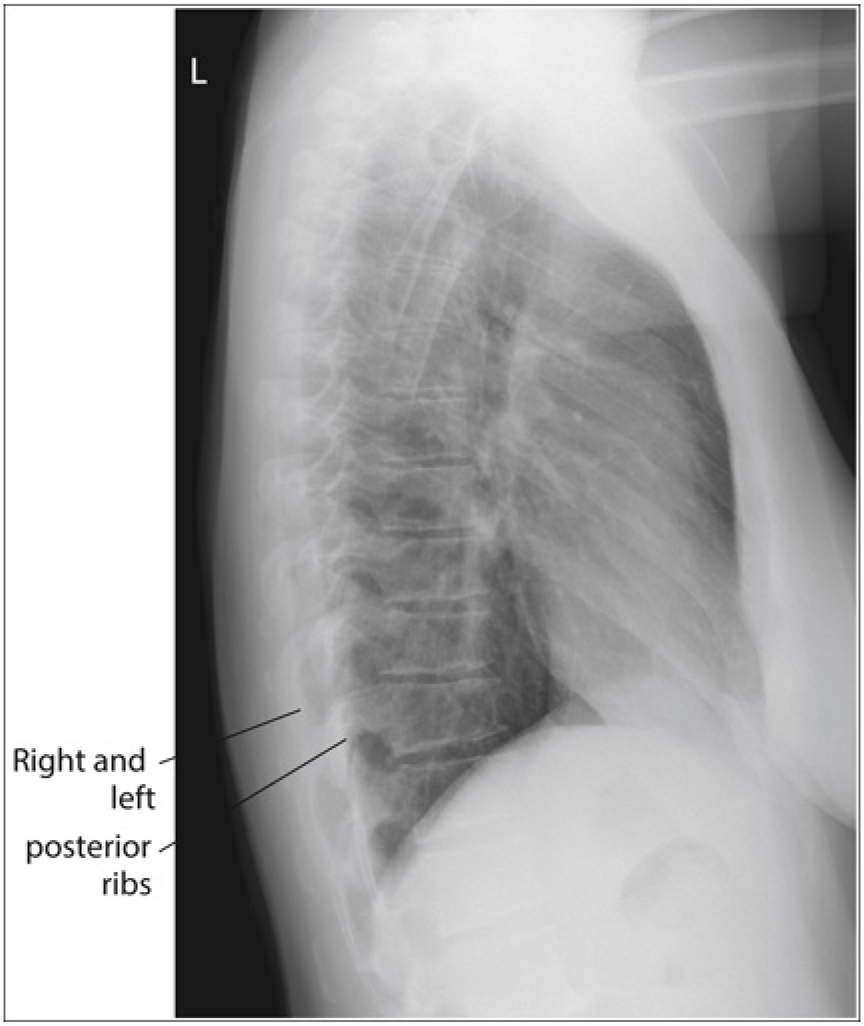


FIGURE 1.47 Left lateral chest projection showing increased magnification of right lung field due to increased OID. Differences in magnification can be noticed between one side of a structure when compared with the opposite side if they are at significantly different OIDs. This can be seen on an accurately positioned lateral chest projection, which demonstrates approximately 0.5 inch (1 cm) of space between the right and left posterior ribs, even though both sides of the thorax are of equal size. Because the right lung field and ribs are positioned at a greater

OID than the left lung field and ribs on a left lateral projection, the right lung field and ribs are more magnified.

FIGURE 1.48 Humerus bones in AP projection without and with elongation.

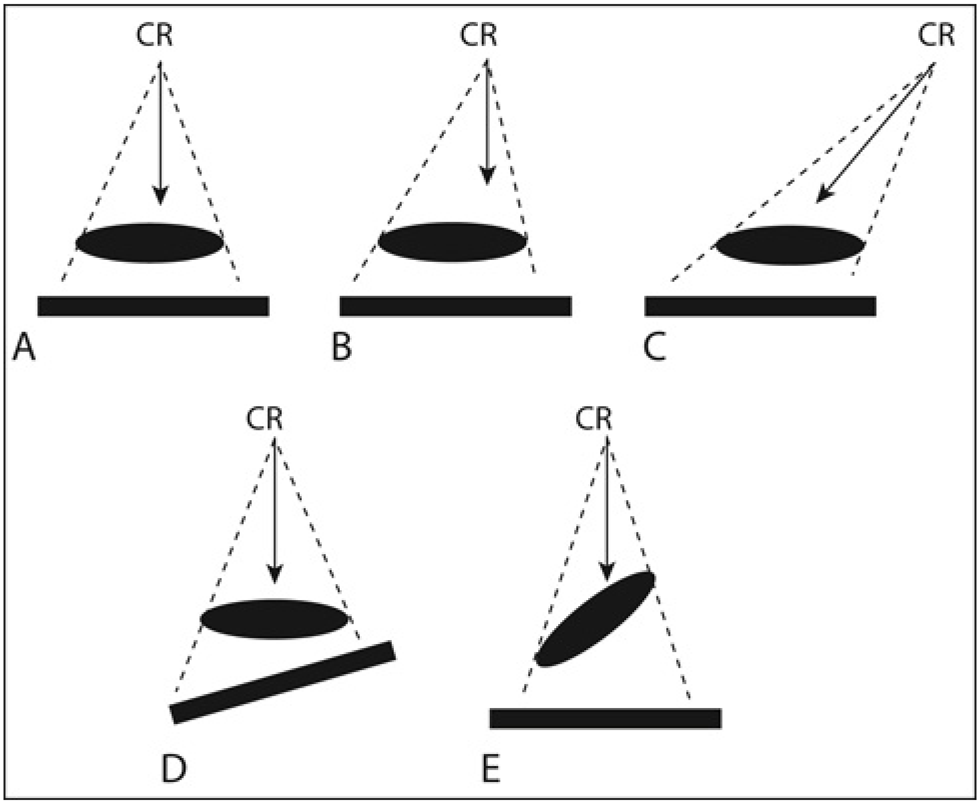


FIGURE 1.49 Best CR, part, and IR alignment for the least distortion (A). Causes of anatomic distortion: 1. The CR is perpendicular to the part and the image receptor (IR) is parallel with the part (B), but the part is not centered to the CR (off-centered). The greater the off-centering, the greater the elongation. 2. The CR is angled and is not aligned perpendicular to the part, but the IR and the part are parallel with each other (C). The greater the CR angulation, the greater the elongation. 3. The CR and part are aligned perpendicular to each other, but the IR is not aligned parallel with the part (D). The greater the angle of the IR, the greater the elongation. 4. Foreshortening occurs when the CR and IR are perpendicular to each

other, but the part is inclined (E). The greater the incline, the greater will be the foreshortening.

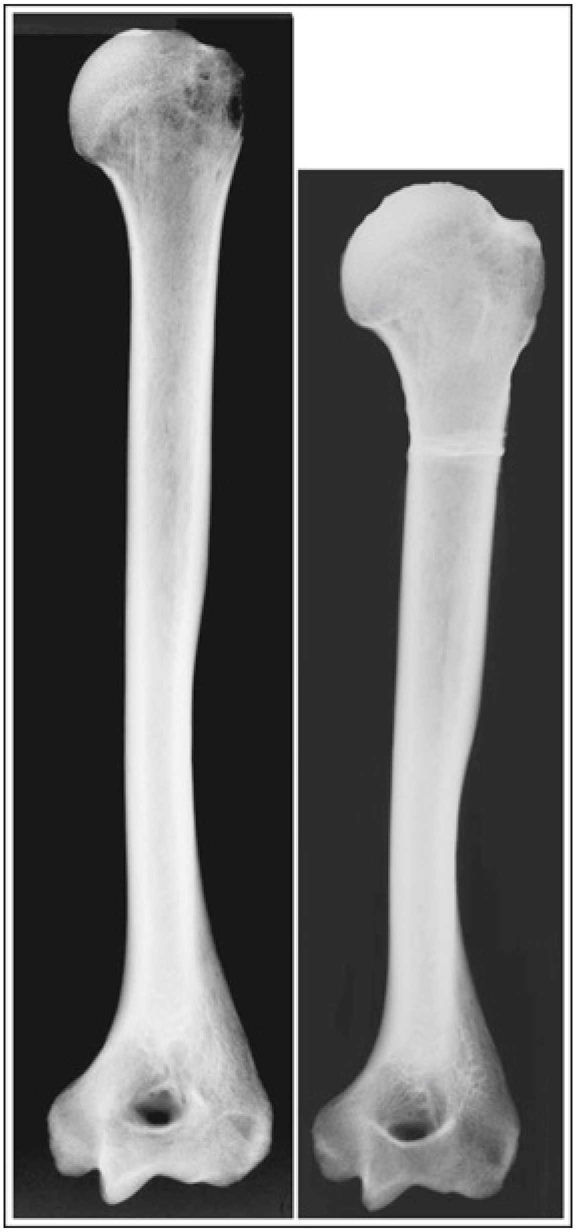


FIGURE 1.50 Humerus bones in AP projection without and with foreshortening.

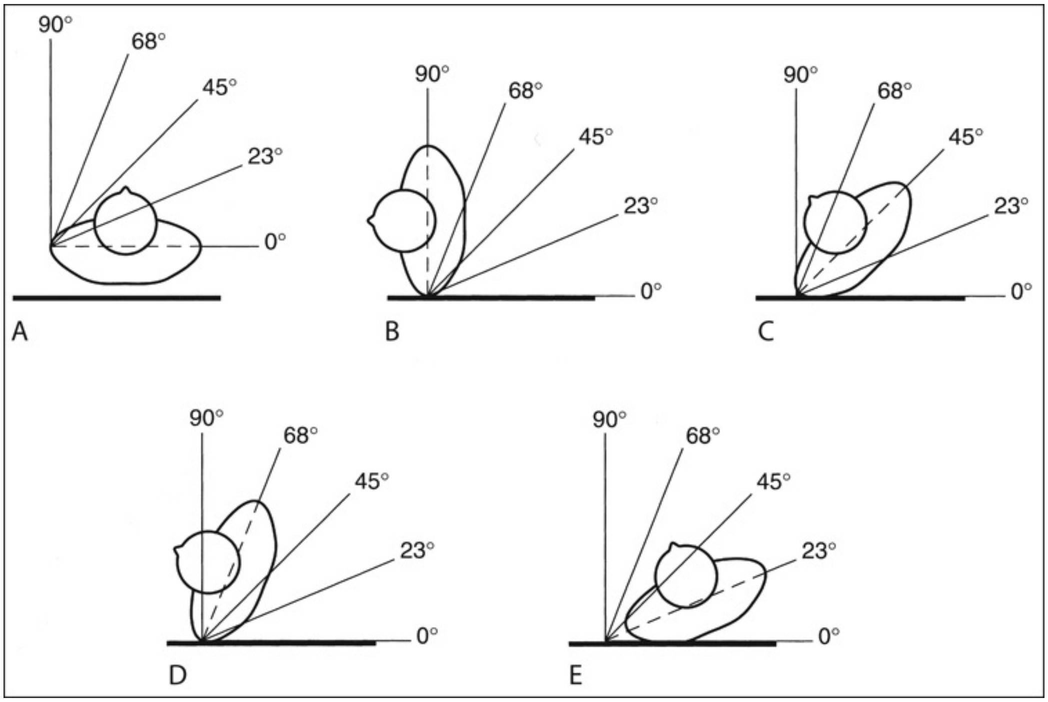


FIGURE 1.51 Estimating the degree of patient obliquity, viewing the patient's body from the top of the patient's head. When the patient is in an AP-PA projection, the reference plane is aligned parallel (0-degree angle) with the IR (A) and, when the patient is in a lateral projection, the reference plane is aligned perpendicular (90-degree angle) to the IR (B). For a 45-degree AP-PA oblique projection, place the reference plane halfway between the AP-PA projection and the lateral projection (C). For a 68-degree AP-PA oblique projection, place the reference plane halfway between the 45- and 90-degree angles (D). For a 23-degree AP-PA oblique projection, place the reference plane halfway between the 0- and 45-degree angles (E). Even though these five angles are not the only angles used when a patient is positioned for projection,

they are easy to locate and can be used to estimate almost any other angle. For example, if a 60-degree AP-PA oblique projection is required, rotate the patient until the reference plane is positioned at an angle slightly less than the 68-degree mark. The torso has been used to demonstrate this obliquity principle, but it can also be used for extremities.

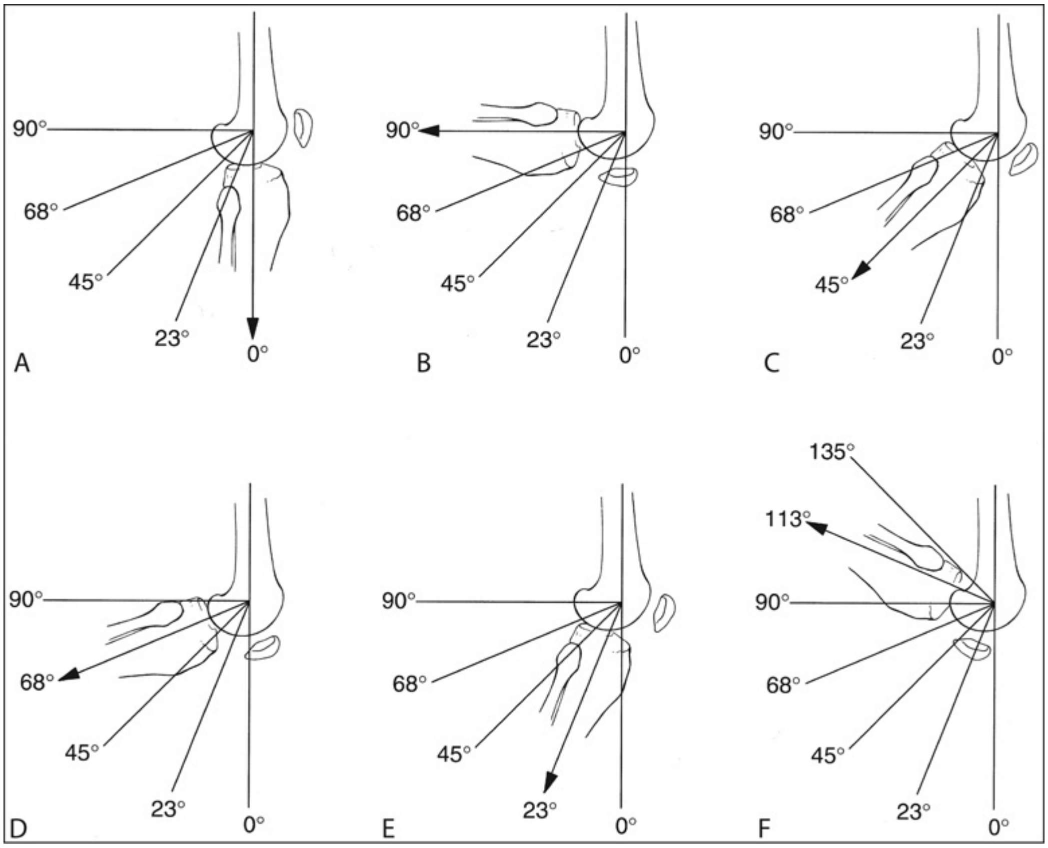


FIGURE 1.52 Estimating the degree of joint or extremity flexion. When an extremity is in full extension, the degree of flexion is 0 (A), and when the two adjoining bones are aligned perpendicular to each other, the degree of flexion is 90 degrees (B). As described in the preceding discussion, the angle found halfway between full extension and 90 degrees is 45 degrees (C). The angle found halfway between the 45- and 90-degree angles is 68 degrees (D), and the angle found halfway between full extension and a 45-degree angle is 23 degrees (E). Because most flexible extremities flex beyond 90 degrees, the 113- and 135-degree angles (F) should also be known.

TABLE 1.5

CR, Central ray; *IR*, image receptor; *OID*, object–image receptor distance; *SID*, source–image receptor distance; *VOI*, values of interest.

Steps for Repositioning the Patient and CR for Repeat Projections

Tables **1.6** and **1.7** list the steps to take when repositioning the patient or the CR after a projection has been obtained that does not meet the required anatomic relationships.

6. Projection Demonstrates Maximum Spatial Resolution

Spatial resolution refers to the ability of an imaging system to record sharp detail edges and distinguish small adjacent details from each other in a projection. The sharpness of the recorded detail on a projection refers to how many pixels the detail's edge will spread across because of blur. Low blur indicates that the spread is minimal, involving fewer pixels and indicating high detail sharpness. The geometric factors that affect blur are the focal spot size and distances. The greatest edge sharpness is obtained by using a small focal spot, the longest possible source–image receptor distance (SID), the shortest possible object–image receptor distance (OID), and controlling motion. It is also greatest in computed radiography when the smallest possible IR cassette is chosen.

It is the digital system's pixel size that determines the minimum size a detail can be and still be resolved and how far adjacent details have to be from each other for them both to be resolved. The term *spatial frequency* is used to describe the expected quality of the spatial resolution that is obtained by a digital system at a set focal spot size and using a set SID and OID. Spatial frequency is defined in terms of the number of details that can clearly be visualized in a set amount of space (distance). This change is not

expressed as the size of the object but in terms of the largest number of line pairs per millimeter (lp/mm) that can be seen when a resolution line pair test tool is imaged using the system. As the geometry is improved by using a small focal spot, increasing the SID, or decreasing the OID, the spatial frequency number will become larger and the ability of the system to resolve smaller details increases. Spatial frequency is directly related to pixel size because each pixel can only visualize one gray shade, distinguishing only one detail, and two pixels are needed to make up a line pair. If the frequency of change in the projection from detail to detail is closer together than the width or height of the pixel, the details will not be resolved (**Table 1.8**).

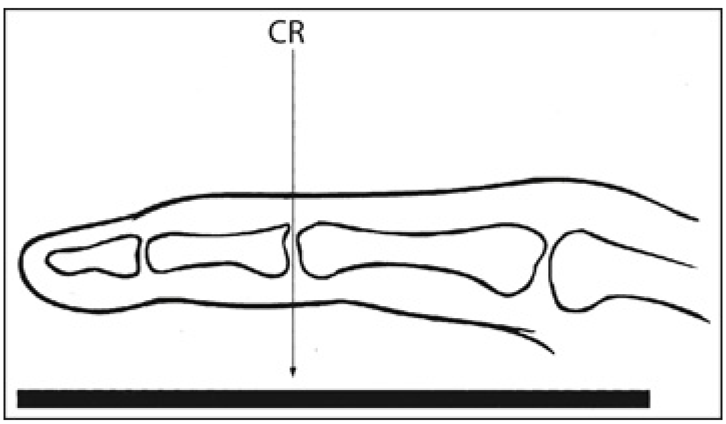


FIGURE 1.53 Accurate alignment of joint space and CR.

FIGURE 1.54 AP finger projection with open joints.

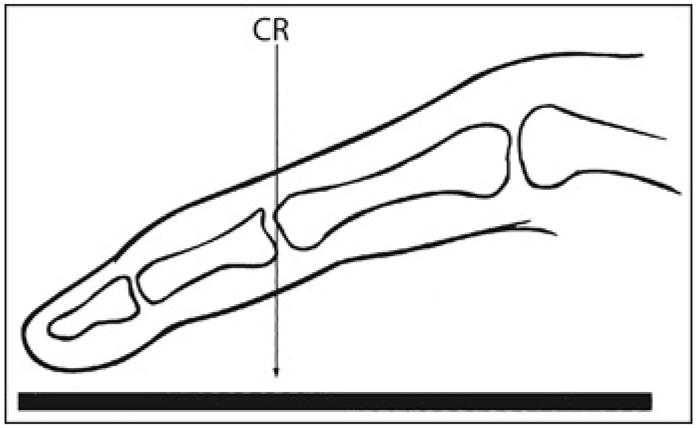


FIGURE 1.55 Poor alignment of joint space and CR.

FIGURE 1.56 PA finger projection with closed joints.

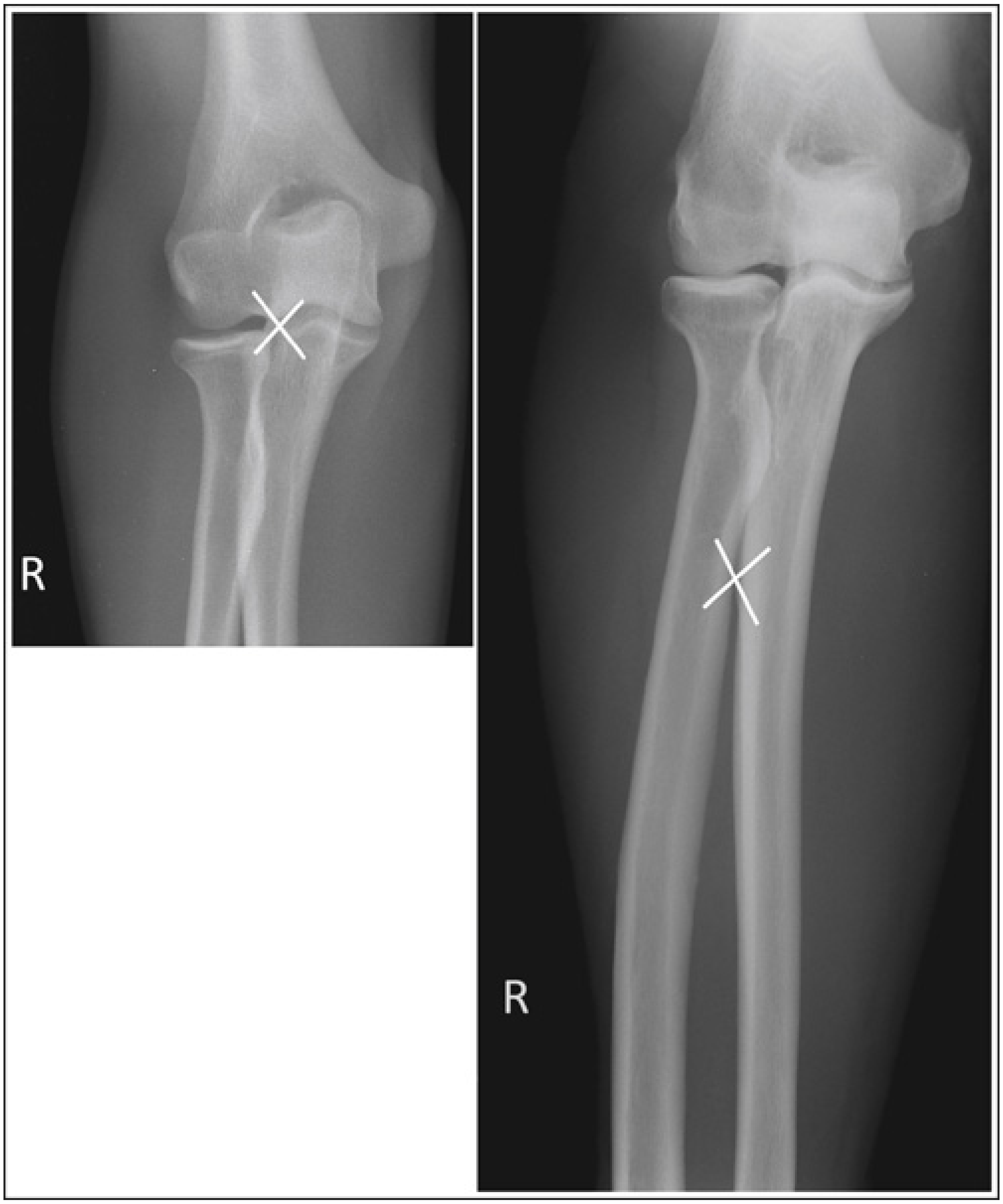


FIGURE 1.57 AP elbow projections comparing the effects of CR centering on joint visualization.

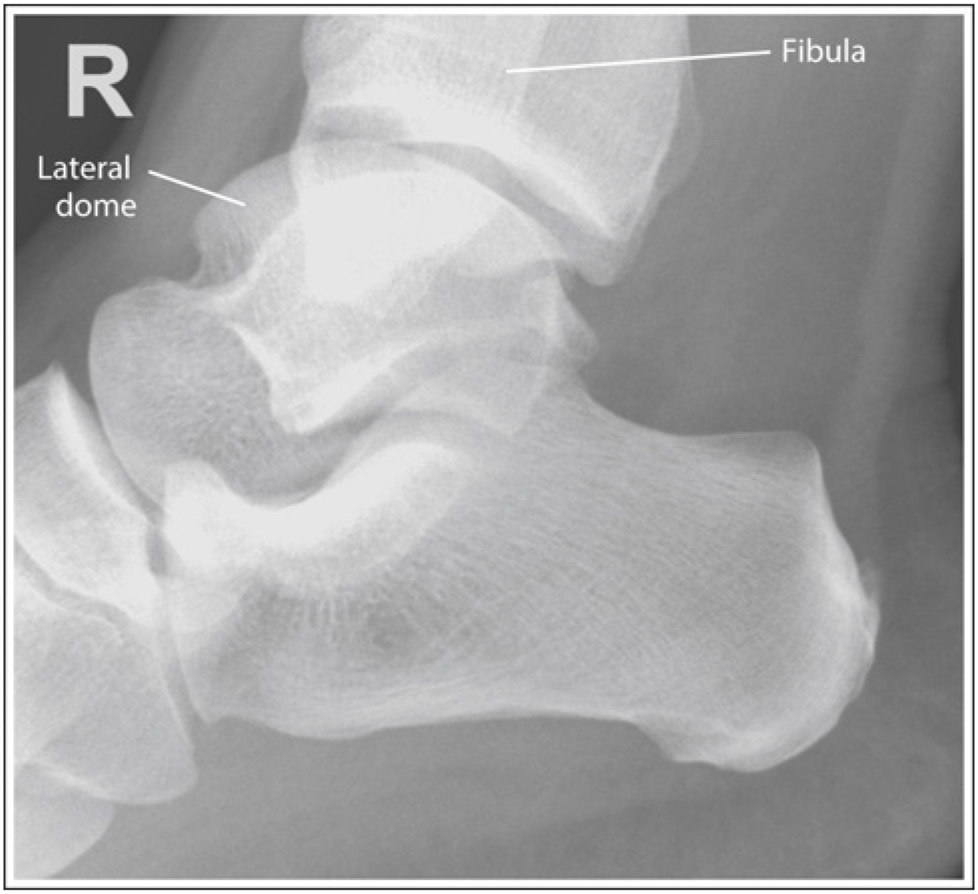


FIGURE 1.58 Poorly positioned right lateral ankle projection. A lateral ankle projection demonstrates inaccurate anterior alignment of the talar domes and a closed tibiotalar joint space. One cannot view the joint space or distinguish between the talar domes to determine which talar dome is the more anterior, but the relationship of the tibia and fibula can easily be used to deduce this information. An accurately positioned lateral ankle projection demonstrates superimposed talar domes and the fibula demonstrated in the posterior half of the tibia. If a lateral ankle is obtained that demonstrates the talar domes without superimposition and the fibula too anterior on the

tibia, the anterior talar dome will be the lateral dome because the lateral dome will move in the same direction as the fibula.

TABLE 1.6

Steps for Repositioning the Patient for Repeat Projections (Figs. 1.59 and 1.60)

1. Identify the two structures that are mispositioned. 2. Determine the number of inches (cm) that the two mispositioned structures are “off.” 3. Determine if the two structures will move toward or away from each other when the main structure is adjusted. 4. Begin the repositioning process by first positioning the patient as he or she was positioned for the poorly positioned projection. From this positioning, move the patient as needed for proper positioning. 5. If the structures move in opposite directions from each other when the patient is repositioned, adjust the patient half of the distance that the structures are off. 6. If only one structure moves when the patient is repositioned, adjust the patient so that the structure that moves is adjusted the

full amount.

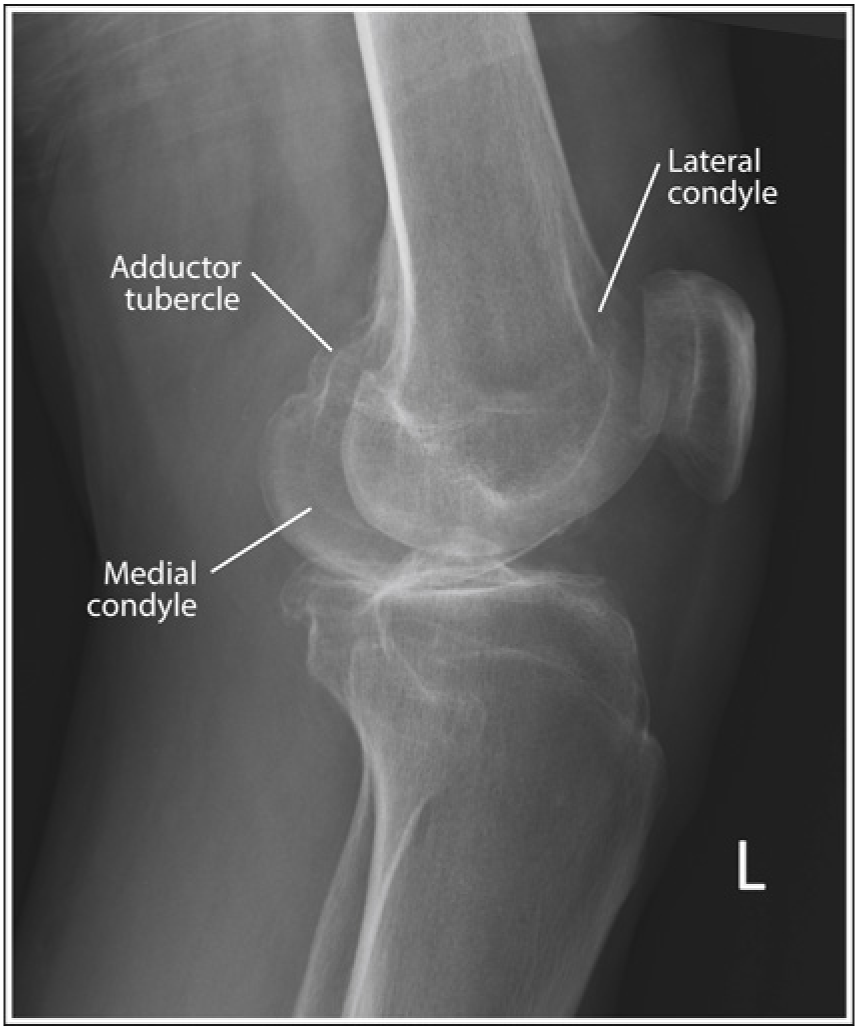


FIGURE 1.59 Poorly positioned left lateral knee projection. The medial femoral condyle can be distinguished from the lateral condyle on a lateral knee projection by locating the adductor tubercle which is situated on the posterior aspect of the medial condyle. The anterior and the posterior surfaces of the medial and lateral femoral condyles should be superimposed on an accurately positioned lateral knee projection. This projection demonstrates that a 0.5-inch (1.25-cm) gap is between them, with the medial condyle positioned more posteriorly. To obtain an optimal

lateral knee projection using patient positioning in this situation (see **Table 1.6**), the medial condyle is rotated anteriorly 0.25 inch (0.6 cm). As the medial condyle is rotated anteriorly the lateral condyle will rotate posteriorly by an equal distance so the amount of repositioning movement needed is only half of the distance between the two rotated structures.

7. Good Radiation Protection Practices Are Used During the Procedure

Diagnostic imaging professionals have a responsibility to adhere to effective radiation protection practices for the following reasons: (1) to prevent the occurrence of radiation-induced nonstochastic effects by adhering to dose-equivalent limits that are below the threshold dose-equivalent levels and (2) to limit the risk of stochastic effects to a reasonable level compared with nonradiation risks and in relation to society's needs, benefits gained, and economic factors.

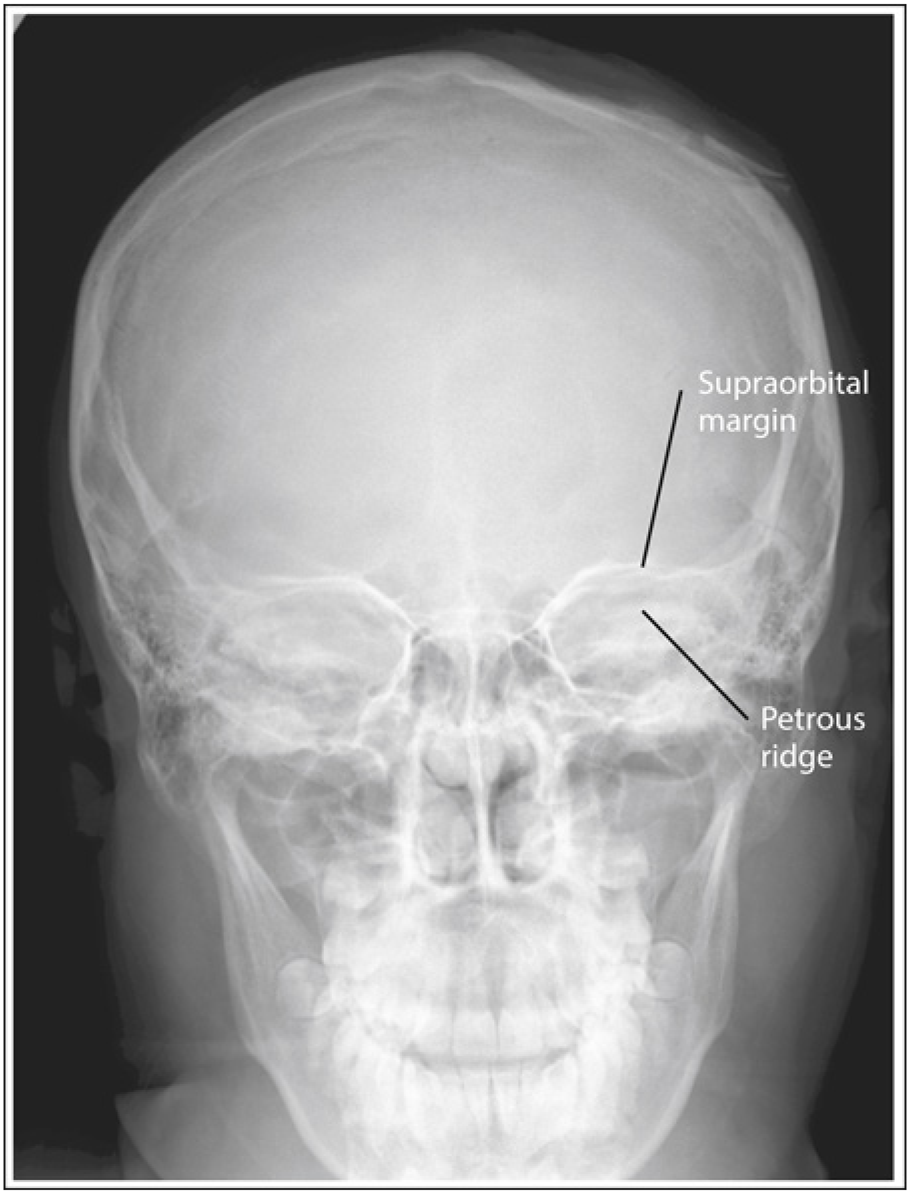


FIGURE 1.60 Poorly positioned AP axial (Caldwell method) cranial projection. An accurately positioned AP axial cranial projection demonstrates the supraorbital margins 1 inch (2.5 cm) superior to the petrous ridges. This AP axial cranial projection demonstrates superimposition of the supraorbital margins and petrous ridges. When the chin is elevated away from the chest, the supraorbital margins move

superiorly, whereas the petrous ridges, being located at the central pivoting point in the cranium, do not move. To obtain an optimal projection by repositioning the patient, the chin is adjusted 1 inch (2.5 cm) away from the chest, moving the supraorbital margins superiorly and 1 inch (2.5 cm) above the petrous ridges. To obtain an optimal projection by adjusting the CR, determine that the supraorbital margins are the farthest from the IR and that they will need to be moved 1 inch (2.5 cm) superiorly to obtain optimal alignment with the petrous ridges. Measure the physical distance between the petrous ridges and supraorbital margins on a skeletal structure, which will be found to be approximately 3 inches (7.5 cm), and then use the chart in **Table 1.7**, step 5, to determine the degree of angulation adjustment that is needed to move the supraorbital margins 1 inch (2.5 cm) superiorly, and adjust the CR angulation by 10 degrees cephalically before repeating the projection.

More than adults, children are susceptible to low levels of radiation because they possess many rapidly dividing cells and have a longer life expectancy. In rapidly dividing cells, the repair of mutations is less efficient than in resting cells. When radiation causes DNA mutations in a rapidly dividing cell, the cell cannot repair the damaged DNA sufficiently and continues to divide; therefore the DNA remains in disrepair. The risk of cancer from radiologic examinations accumulates over a lifetime, and because children have a longer life expectancy, they have more time to

manifest radiation-related cancers. This is particularly concerning because many childhood diseases require follow-up imaging into adulthood.

TABLE 1.7

Steps for Repositioning the Central Ray for Repeat Projections (Figs. 1.60 and 1.61)

1. Identify the two structures that are mispositioned. 2. Determine which of the identified structures is positioned farthest from the IR. This is the structure that will move the most when the CR angle is adjusted. 3. Determine the direction that the structure situated farthest from the IR must move to be positioned accurately with respect to the other structure. 4. Determine the number of inches (cm) that the two mispositioned structures are off on the projection. 5. Estimate how much the structure situated farthest from the IR will move per 5 degrees of angle adjustment placed on the CR. How much the CR angulation projects two structures away from each other depends on the difference in the physical distance of the structures from each other, as measured on the skeletal bone. • If the identified physical structure (actual bone, not as seen on radiographic image) is separated by 0.5–1.25 inches (0.16–3.2

cm), a 5-degree CR angle adjustment will move the structure situated farthest from the IR by approximately 0.125 inch (0.3 cm).

- If the identified physical structures are separated by 1.5–2.25 inches (3.75–6 cm), a 5-degree CR angle adjustment will move the structure situated farthest from the IR approximately 0.25 in (0.6 cm).
- If the identified physical structures are separated by 2.5–3.25 inches (6.25–8 cm), a 5-degree CR angle adjustment will move the structure situated farthest from the IR approximately 0.5 inch (1.25 cm).
- If the identified physical structures are separated by 3.5–4.5 inches (8.75–11 cm), a 5-degree CR angle adjustment will move the structure situated farthest from the IR approximately 0.75 inch (1.9 cm).

6. Place the needed angulation on the CR, as determined by steps 4 and 5, and direct the CR in the direction indicated in step 3.

CR, Central ray; *IR*, image receptor.

Continually evaluating one's radiation protection practices is necessary because radiation protection guidelines for diagnostic radiology assume a linear, nonthreshold, dose-risk relationship. Therefore any radiation dose, whether small or large, is expected to produce a response. Even when radiation protection efforts are not seen on the resulting projection itself, good patient care standards dictate their use. **Table 1.9** lists radiation

protection practices that, when followed, fulfill the ALARA (as low as reasonably achievable) philosophy.

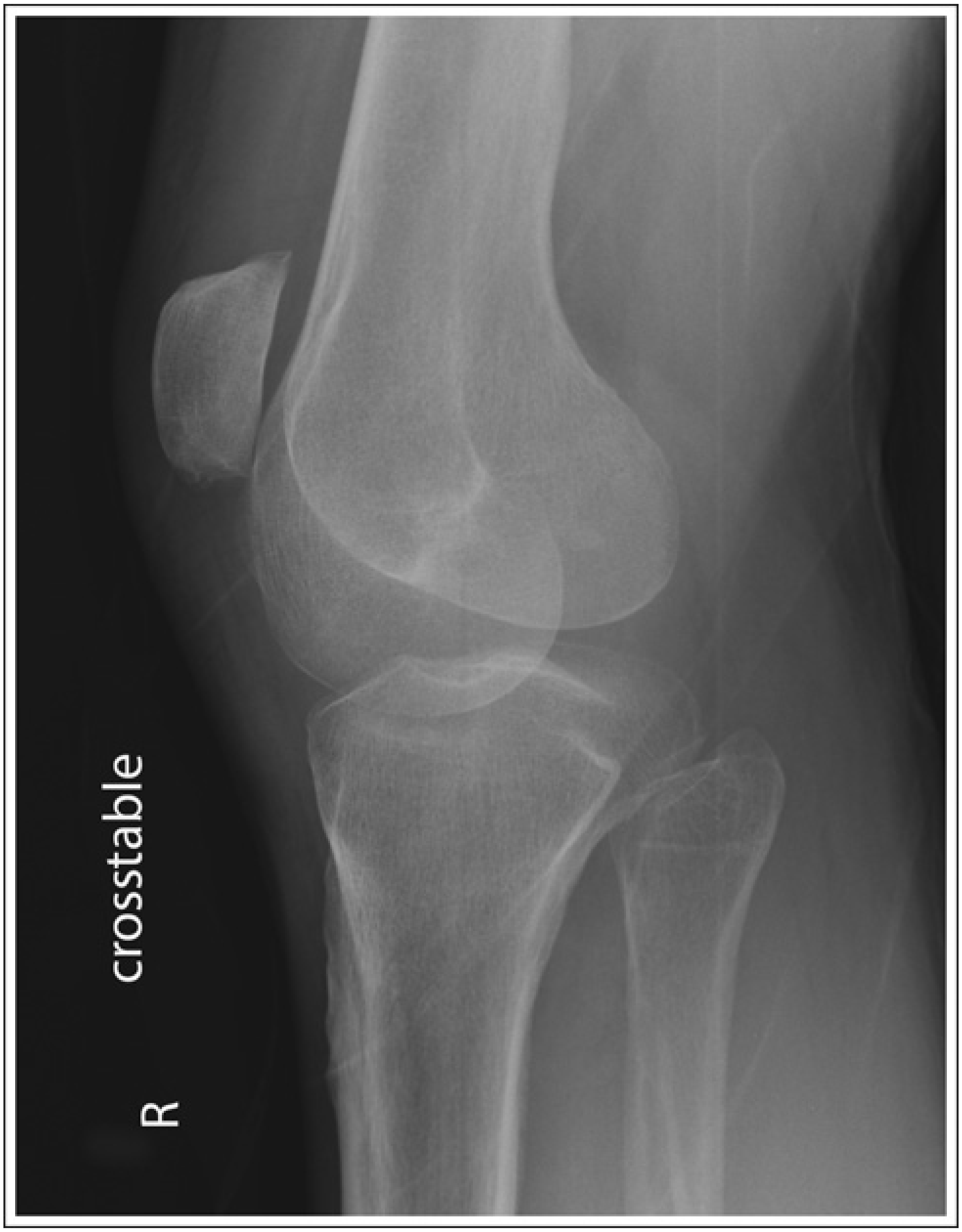


FIGURE 1.61 Poorly positioned cross-table lateromedial knee projection. The cross-table lateral knee projection demonstrates the medial femoral condyle anterior and distal to the lateral femoral condyle. An optimally positioned lateral knee projection should demonstrate superimposition of the femoral condyles. Because the patient is unable to

rotate or move the leg for this projection, the CR needs to be adjusted to obtain an optimal projection. The physical space between the femoral condyles of the knee, as measured on a skeletal bone, is approximately 2 inches (5 cm). Using the CR adjustment guidelines in **Table 1.7**, step 5, we find that structures that are 2 inches apart will require a 5-degree CR angle adjustment to move the part situated farthest from the IR 0.25 inch (0.6 cm) more than the structure situated closer to the IR. The medial condyle is situated closer to the IR so the lateral condyle is the one that will be moved with a CR adjustment. Because the anterior and distal femoral separation is 1 inch (2.5 cm), the CR will need to be angled 20 degrees cephalically to move the lateral condyle anteriorly to align with the anterior surface of the medial condyle, and the x-ray tube will need to be rotated 20 degrees caudally to move the lateral condyle distally to align with the medial condyle.

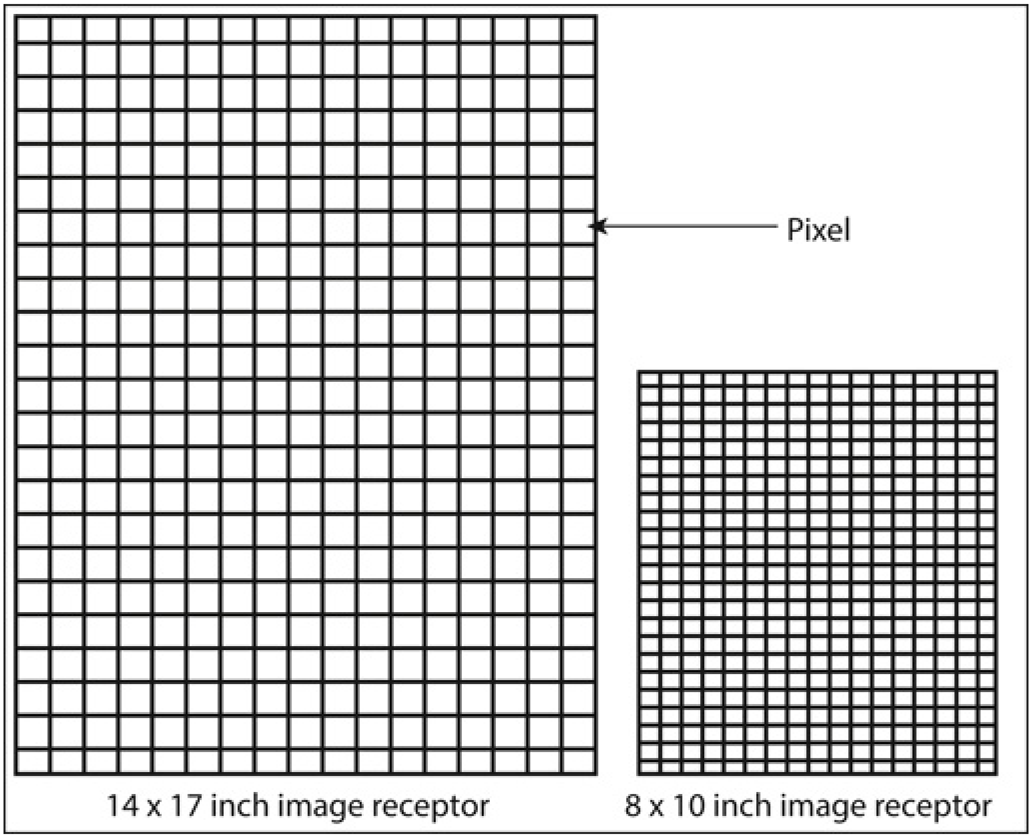


FIGURE 1.62 Computed radiography systems have a set matrix size. The image matrix refers to the layout of pixels in rows and columns and is determined by the system's manufacturer. A larger matrix size will provide a higher number of pixels. The size of the pixels in the matrix is determined by the field of view (FOV). The FOV defines the area on the IR from which data are collected. Because the entire IR is scanned for data during processing, the FOV is the entire IR cassette (imaging plate) and because different cassette sizes are used, the size of the IR chosen influences the size of the FOV, size of pixels, and resulting spatial resolution. A computed radiography system using a matrix size of 1024 × 1024

will divide the image into 1,048,576 pixels. Spreading this matrix over a 14 × 17 inch FOV will result in larger pixel sizes than spreading the matrix over an 8 × 10 inch FOV. Because the 8 × 10 inch IR will contain pixels of smaller size, it will provide superior spatial resolution.

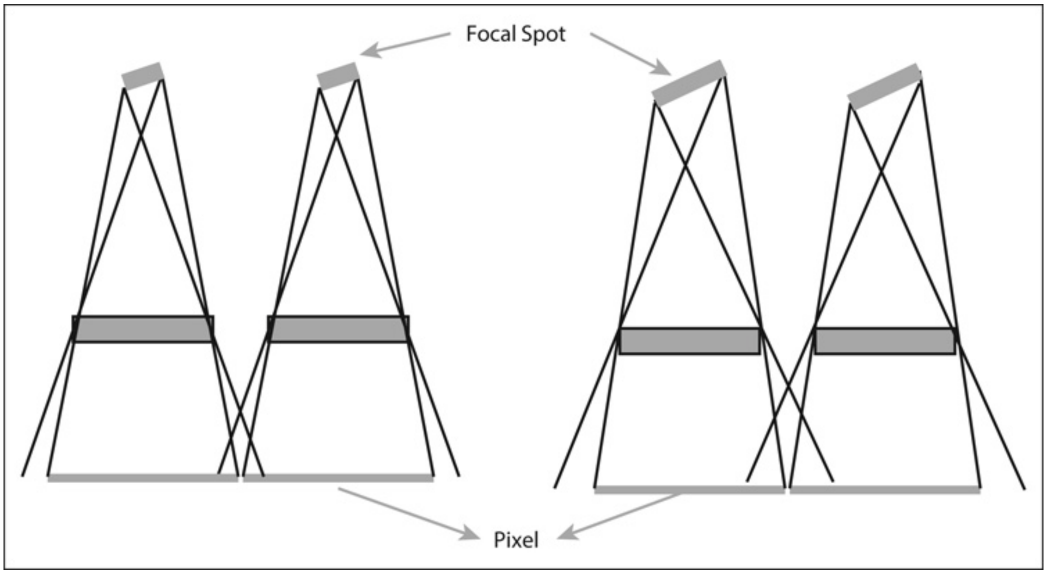


FIGURE 1.63 Focal spot size. The smaller the focal spot size used, the better will be the spatial resolution on the projection because less blur will be spread to the adjacent pixel.

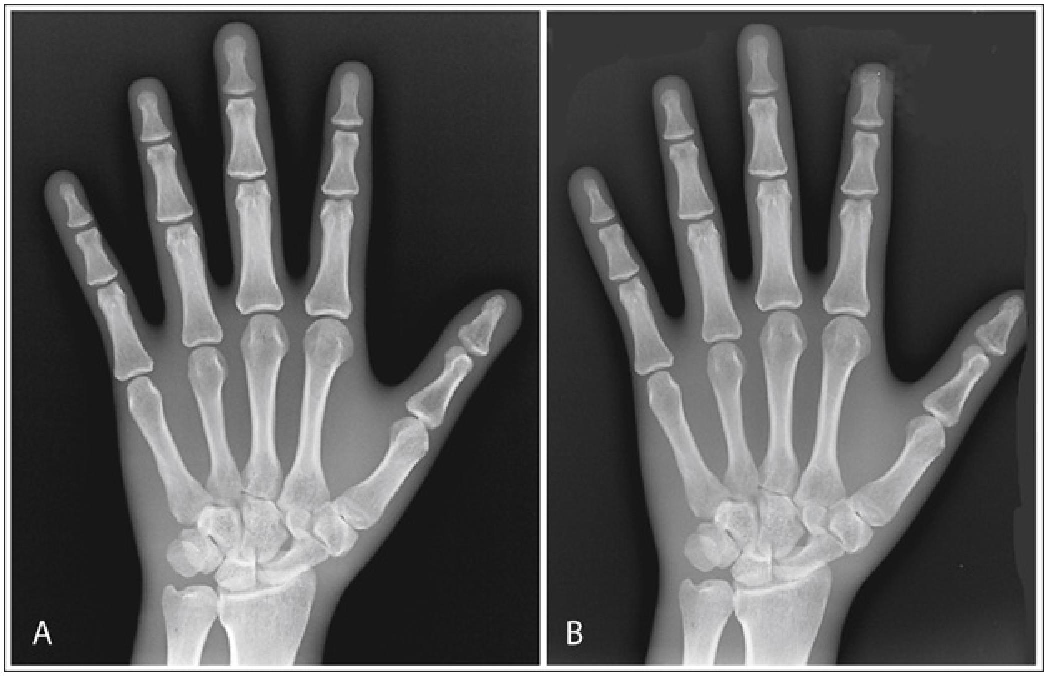


FIGURE 1.64 Choosing a small focal spot over a large focal spot increases the sharpness of the recorded details. The difference between the (A) small and (B) large focal spot will be noticeable at the smallest structures, such as the trabecular patterns and cortical outlines.

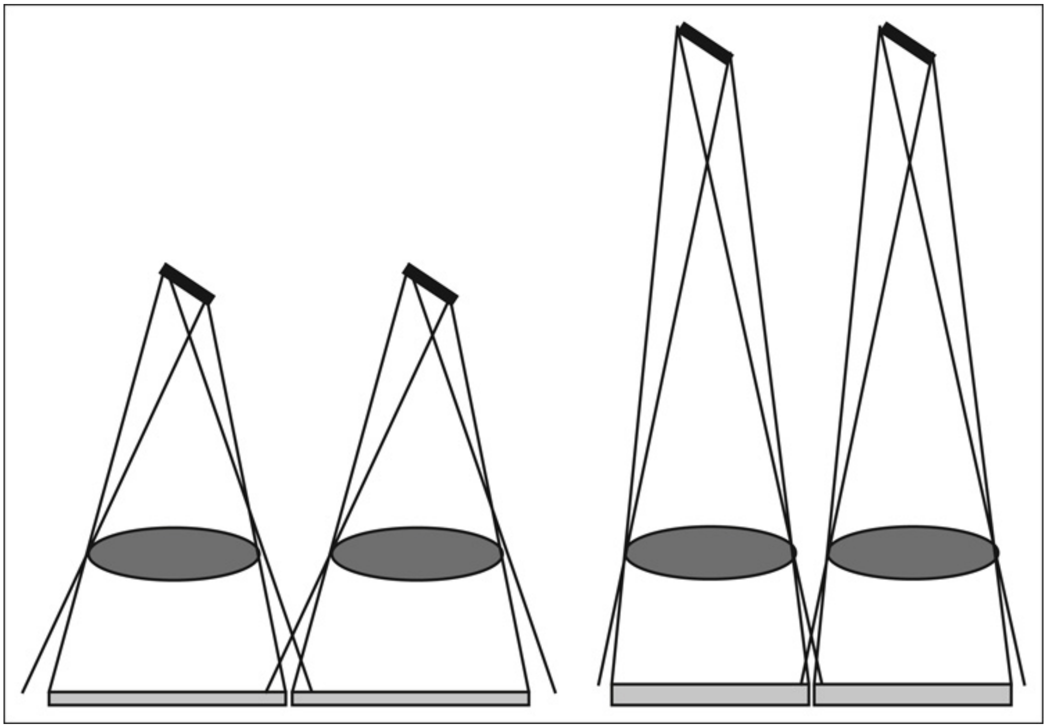


FIGURE 1.65 SID and spatial resolution. The longer the SID, the sharper the recorded details because the beams recording the detail edges are nearer to the CR and recorded with straighter x-rays.

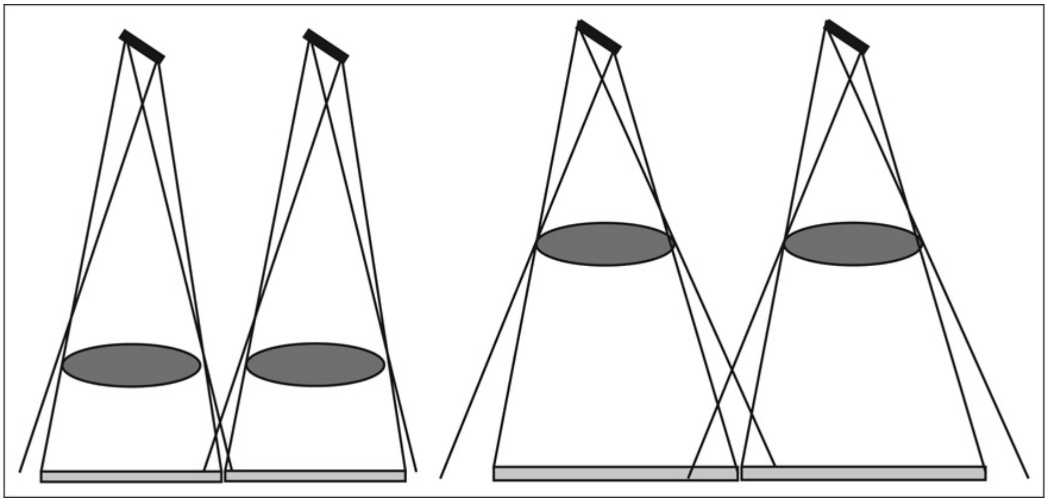


FIGURE 1.66 OID and spatial resolution. The shorter the OID, the better the spatial resolution.

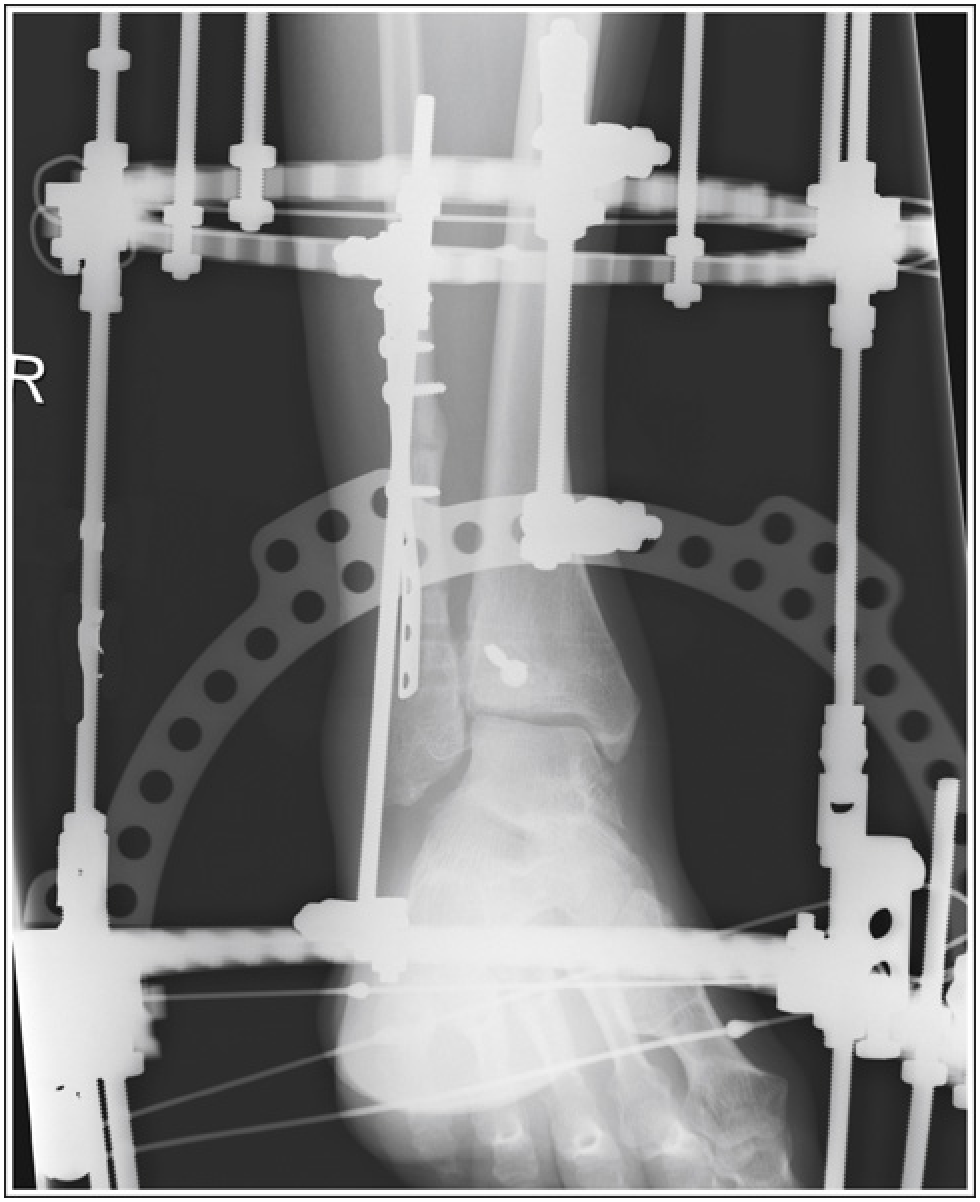


FIGURE 1.67 AP ankle projection obtained at a long OID because of traction device. In nonroutine clinical situations, the technologist may be unable to get the part as close to the IR as possible. One example of this is a patient who is unable to straighten the knee for an AP projection or is in traction as demonstrated in the AP ankle projection. For this situation the ankle would be at an increased OID that could not be avoided. To

offset magnification the SID can be elevated above the standard, and equal magnification will result if the ratio between the SID and OID remain the same. A projection taken at a 1-inch OID and 40-inch SID would demonstrate the same magnification as one taken at a 4-inch OID and 160-inch SID because both have a 1:40 ratio. It is often not feasible to increase the SID the full amount needed to offset the magnification completely because the SID cannot be raised that high.

TABLE 1.8

CR, Central ray; *DEL*, detector element; *FOV*, field of view; *IR*, image receptor; *OID*, object–image receptor distance; *SID*, source–image receptor distance.

FIGURE 1.68 Anteroposterior oblique knee projection demonstrating voluntary patient motion.

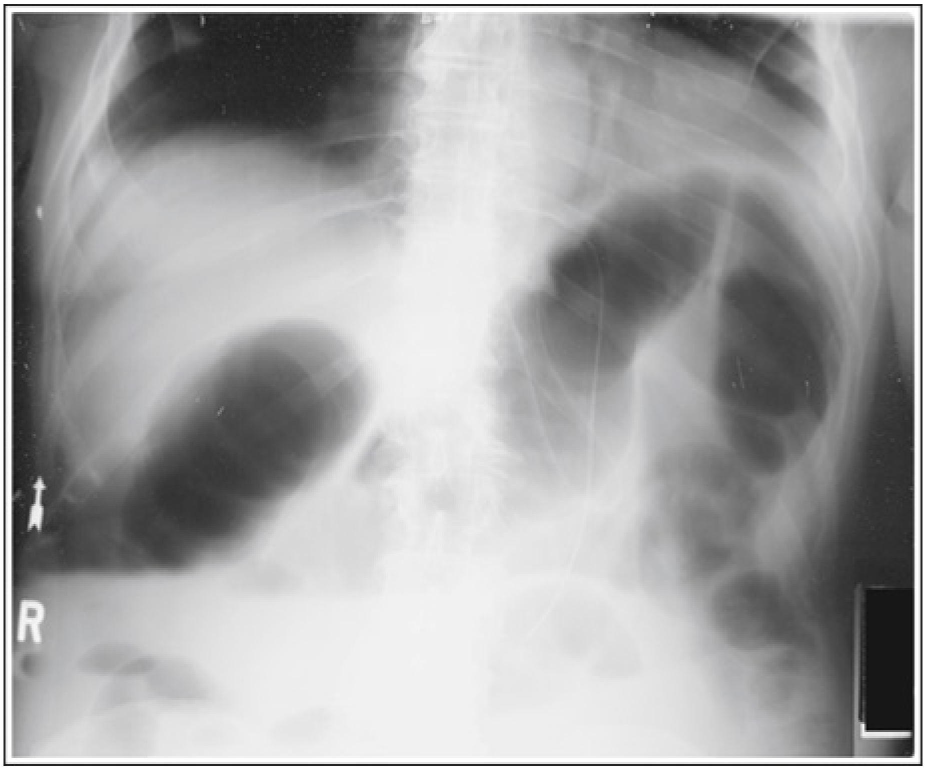


FIGURE 1.69 Involuntary patient motion on AP abdomen projection.

FIGURE 1.70 Double-exposed AP and lateral vertebral projections.

FIGURE 1.71 Double-exposed AP abdomen projections with barium in stomach and intestines.

FIGURE 1.72 Lateral hand projection with an anatomic artifact. Anatomic artifacts are structures other than what is required that are demonstrated on the projection. Note in the figure how the patient's other hand was used to help maintain the lateral hand position. This is not an acceptable practice. Many sponges and other positioning tools are available to aid in positioning and immobilization of the patient. Whenever the hands of the patient, x-ray personnel, or

others must be within the radiation field, they must be properly attired with lead gloves.

TABLE 1.9

AEC, Automatic exposure control; *EI*, exposure index; *OID*, object–image receptor distance; *SID*, source–image receptor distance; *SSD*, source-skin distance; *VOI*, values of interest.

Chapter 2: Visibility of Details

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Describe the processing steps completed in computed radiography and direct-indirect digital radiography (DR).
- State why the exposure field recognition process is completed in computed radiography and is not needed in DR.

- Identify the areas of an image histogram and list the guidelines to follow to produce an optimal histogram.
- Explain the relationship between the image histogram and the chosen lookup table in the automatic rescaling process.
- Discuss the causes of a histogram analysis error.
- List the exposure indicator parameters for the digital systems used in your facility, and discuss how to use them to evaluate and improve the quality of projections.
- Describe how to identify when a projection has been overexposed and underexposed.
- State the causes of overexposure and underexposure in digital radiography and the effect that each has on image quality.
- Describe the factors that affect contrast resolution.
- List the different artifacts found in radiography, and discuss how they can be prevented, when applicable.
- Discuss the difference between an optimal and an acceptable projection.
- List the guidelines for obtaining mobile and trauma projections, and state how technical factors should be adjusted to adapt for different mobile and trauma-related conditions.
- Describe the differences to consider when performing procedures and evaluating pediatric and obese patient projections.

KEY TERMS

additive condition algorithm anode heel effect artifact automatic exposure control automatic rescaling backup timer bit depth brightness contrast resolution destructive condition differential

absorption dynamic range exposure field recognition exposure indicator

gray scale histogram histogram analysis error image acquisition imaging plate lookup table moiré grid artifact phantom image postprocessing procedural algorithm quantum noise radiopaque raw data saturation scatter radiation signal to noise ratio subject contrast thin-film transistor windowing

Digital Radiography

Two types of digital imaging systems are used in radiography to acquire and process the radiographic image, the cassette-based system known as computed radiography, and the cassette-less detector system known as direct-capture digital radiography (DR). The systems are unique in the methods that they use to acquire and process the image before sending it to the computer to be analyzed and manipulated. Understanding the acquisition and processing steps of each system will help the technologist prevent errors that cause poor acquisition and processing and understand the indicators used to analyze the quality and improve the radiographic projection.

Image (Data) Acquisition

Computed Radiography

Computed radiography uses cassettes that envelope an imaging plate (IP) as the image receptor (IR) that can be placed in the Bucky or on the imaging tabletop to obtain the projections. Prior to the exposure, the computed radiography cassette is associated with the patient, body part, and projection at the workstation. Selecting the correct body part and projection ensures that the correct algorithm type will be used during the histogram analysis

process and that the correct lookup table (LUT) is applied when the image is rescaled. During the image acquisition process, the radiographic exposure absorbed by the IP causes ionization and the released electrons to be trapped in the IP's photostimulable phosphor. The number and distribution of the trapped electrons in each area of the IP represent the differential absorption and latent image of the body part being radiographed. Once the IP has been exposed, the cassette is loaded, and the IP is extracted and sent to the reader unit. The IP is divided into a matrix with rows and columns of pixels, and a laser beam is scanned back and forth across the plate, releasing the trapped electrons, resulting in the ionized atoms moving to a neutral state and the extra energy from the photon being released as visible light through a process called photostimulable luminescence. The emitted light is directed through the light channeling guide to the photomultiplier tube (PMT), where it is amplified and converted to an electrical signal and then sent to the analog-to-digital converter (ADC) to be digitized. During digitization, each pixel is assigned a digital value that represents the amount of light that was emitted from that surface of the IP. Pixels that received greater IR exposure are assigned values that represent darker gray shades, whereas the pixels receiving less exposure are assigned values that represent lighter gray shades. All the digital numbers (gray shade values) together make up what is referred to as the *raw data*. Prior to the creation of the histogram, a partitioned pattern recognition (also called *segmentation*) algorithm is applied to the data to identify and count the number of projections that have been obtained using a single photostimulable phosphor plate (PSP) so that each can be processed separately.

Direct-Capture Digital Radiography

Direct-capture DR uses a cassette-less imaging capture system that is hard-wired to the image processing system and does not require the technologist to physically place the IR into the reader. Prior to the exposure, the technologist must choose the correct patient and projection from the workstation to ensure that the correct histogram analysis and LUT are applied to the image before it is displayed. The IR contains a matrix of pixel-size radiation absorption areas called *detector elements* (DELs) that release electrical charges upon exposure, and includes a capacitor that stores the released electric charges, and an electronic circuit called a thin-film transistor (TFT) that works to capture the electrical charges and releases them at read out. The latent image in the remnant radiation is represented by the TFTs capturing varying intensities in the capacitors. After the exposure, the TFTs open the switches sending the stored electrical charges to the computer in an orderly manner for processing and manipulation where each DEL signal is given a digital number that represents the gray shade value. Only the DELs in the TFT that have received radiation, which is determined when the technologist collimates, collect and send electric signals and are included in the image. This eliminates the need for the partitioned pattern recognition process that is completed in computed radiography and the many histogram errors that poor recognition can cause.

Histogram Construction

After the raw data have been acquired in both computed radiography and DR, a histogram graph is generated that has the pixel gray shade values on the *x*-axis and the number of pixels with that gray shade value on the *y*-axis (**Fig. 2.1**). The peaks and valleys in the histogram represent the subject contrast in the remnant radiation and are determined by the total exposure

(kV and mAs selected) that is used and the resulting differential absorption that creates the latent image. Gray shade values between white to black are positioned on the histogram from left to right, with the metallic objects and contrast mediums recorded on the left in the graph, followed by bone, soft tissues near the center, fat, and finally gaseous or air values on the right. The tail or high spiked portion on the far right of some histograms represents the pitch black background value that is outside the values of interest (VOI; those that represent the anatomical structures of interest) and in the exposure field. This background value will be the darkest value because this area is exposed to primary radiation that does not go through any part of the patient, such as with extremity and chest projections that have been collimated close to the skin line but not within it (**Fig. 2.2**). The spike is referred to as the raw exposure area and is not visible on projections in which the entire IR is covered with anatomy, such as abdomen projections or projections in which the collimation field is within the skin line, such as for an anteroposterior (AP) lumbar vertebrae projection.

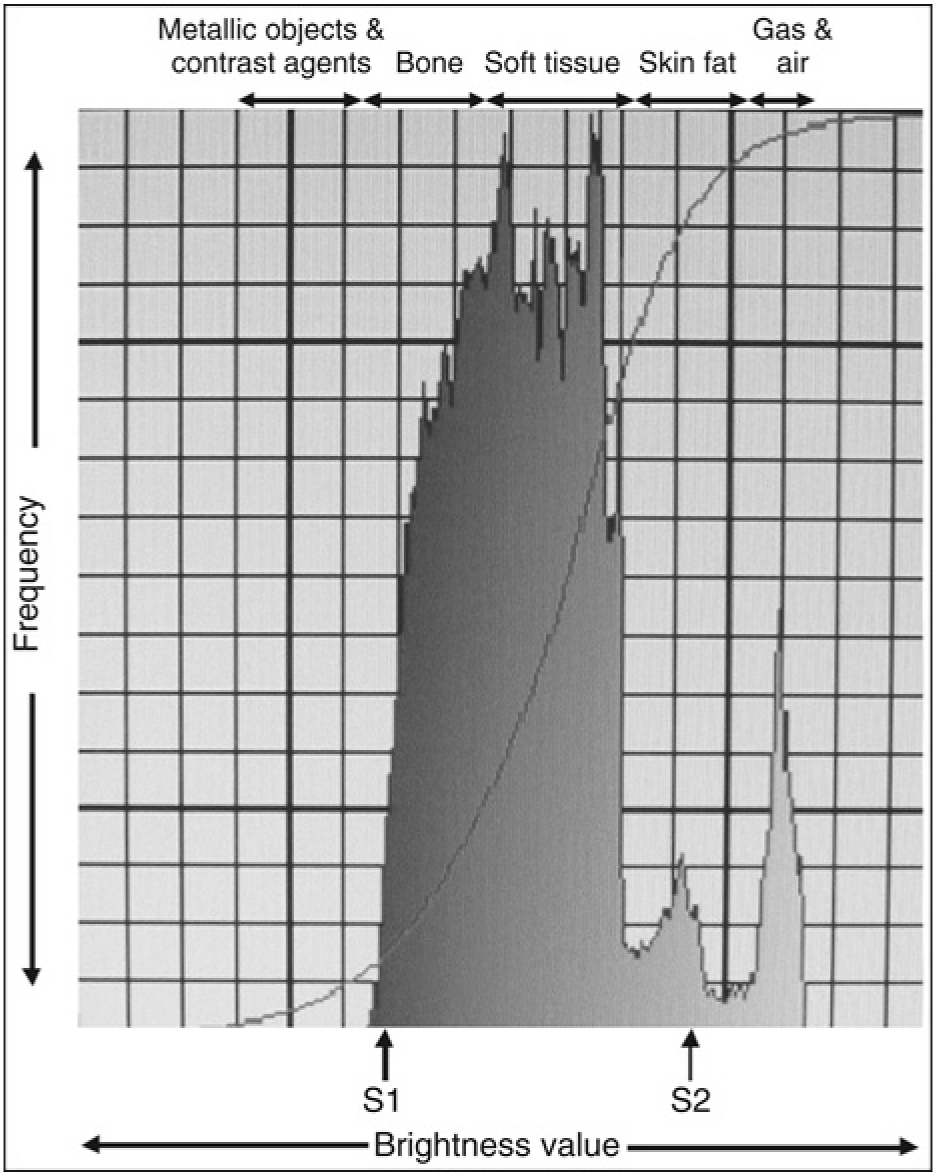


FIGURE 2.1 Histogram.

When optimal procedure practices are used (**Table 2.1**), because the subject contrast of a particular anatomic structure (e.g., chest, abdomen, shoulder) is fairly consistent from exposure to exposure, the shape of each procedure's histogram is fairly consistent as well.

Exposure Field Recognition

Before the image histogram is created, it is analyzed to identify the data that is part of the VOI from all other data background exposure, positive contrast mediums, nonremovable metallic objects (i.e., prostheses), and radiopaque artifacts, so that only the range of pixel data from the anatomical VOI is sent to the LUT for rescaling. This is accomplished by applying an exposure field recognition algorithm. During this process, the computer scans inward from both ends of the image histogram until it identifies the first gray shades that contain a pixel count or a threshold number (a specific number of pixels in the column is reached) of pixels on each end (**Fig. 2.3**). The shade value that is identified on the left is labeled S_{min} and represents the minimum useful gray shade value (brightest shade), and the shade value identified on the right is labeled S_{max} and represents the maximum useful gray shade value (least brightness). The analysis will also identify S_{ave}, which is the average pixel value (usually soft tissue) and is located halfway between S_{min} and S_{max}. S_{ave} is used to calculate the exposure index (EI) readings and can be used to determine the accuracy of the IR exposure if there is no exposure field recognition error.

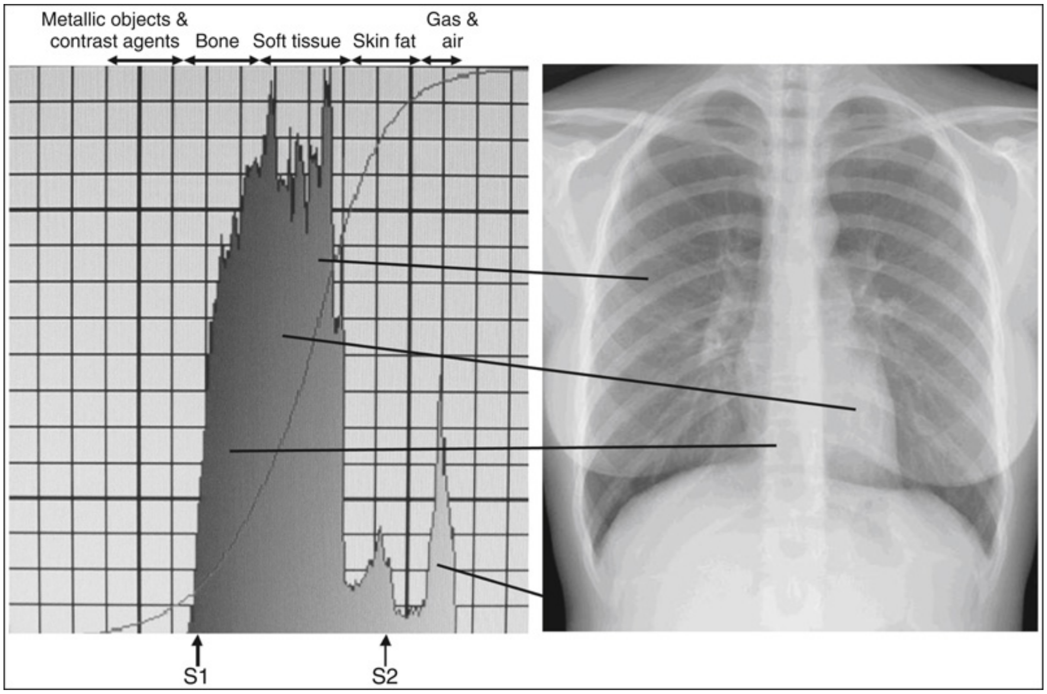


FIGURE 2.2 Histogram of PA chest projection.

TABLE 2.1

Guidelines for Producing Optimal Image Histograms

Computed and Direct-Capture Radiography

- Eliminate any removable artifacts.
- Set the correct technique factors for the projection.
- Choose the correct procedural algorithm (body part and projection) from the workstation menu.
- Center the CR to the center of the VOI.
- Collimate as closely as possible to the VOI, leaving minimum background in the exposure field.
- Control the amount of scatter reaching the IR (grids, collimation, lead sheets).

Computed Radiography Only

- Use the smallest possible IR, covering at least 30% of the IR.
- Erase the IP if the IR has not been used within 48 h.
- If collimating smaller than the IR, center the VOI and show all four collimation borders.
- When placing multiple projections on one IR, all of the collimation borders must be parallel and equidistant from the edges of the IR, and at equal distance from each other.
- Do not leave the IR cassette in the imaging room while other exposures are being made and read the IP shortly after the exposure.
- Process the IR promptly.

Computed and Direct-Capture Radiography

CR, Central ray; *IP*, imaging plate; *IR*, image receptor; *VOI*, values of interest.

Q. B. Carroll in “Radiography in the Digital Age” describes three general types of histogram analysis that are applied to the image histogram. The type that is associated with a particular projection is based on the expected shape of the acquired image histogram and is set when the technologist selects the procedure algorithm (body part and projection) on the workstation. These algorithms are designed to inform the computer to expect certain nonanatomical structures on the histogram, and when they are identified to exclude them from the VOI (**Fig. 2.4**).

Type 1 is associated with procedures (i.e., extremities) that will have raw exposure area between the anatomical structure and the collimation border. The image histogram on these procedures is expected to demonstrate a tail or high spiked area on the far right, and because this tail does not represent an anatomical structure, it should not be included in the VOI. The type 1 applied algorithm will instruct the computer to skip over the dark values that represent this tail when it is scanning inward from the right side to label S_{max}.

Type 2 is associated with procedures (i.e., lumbar spine procedures) that will not have the raw exposure tail on the far right of the image histogram because the procedure requires the technologist to collimate within the skin border of the anatomical structure, excluding any raw exposure area. When this algorithm type is set, the computer does not search for a tail and does not exclude the data on the far right from the VOI.

Type 3 is associated with a procedure when a large radiopaque area is present in the exposure field, such as a positive contrast medium or nonremovable metallic object (i.e., prosthesis), and the image histogram is expected to demonstrate these nearly white values on the far left. The type 3 applied algorithm will instruct the computer to skip over these white values when it is scanning inward from the left to label S_{min}.

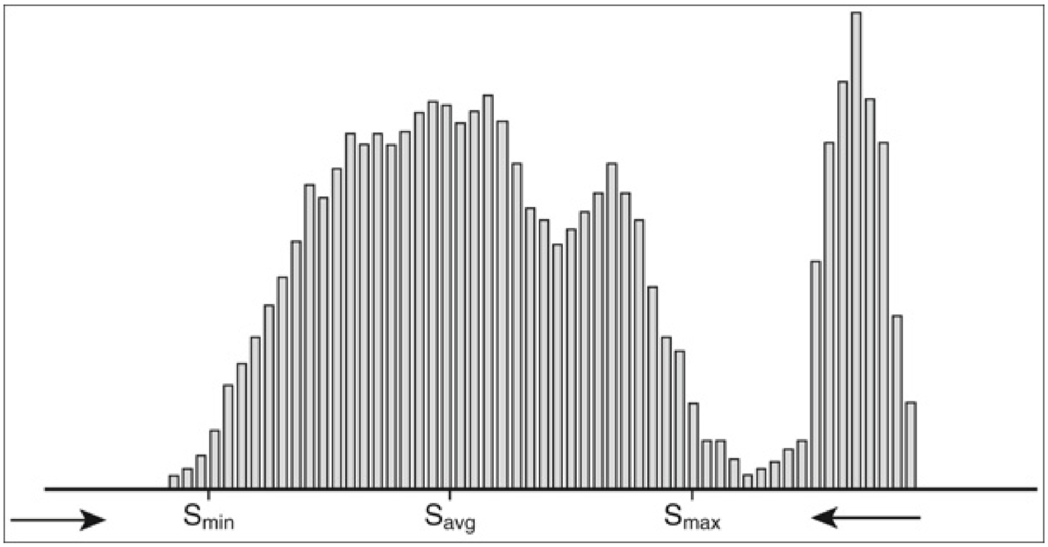


FIGURE 2.3 Identifying the VOI on the image histogram.

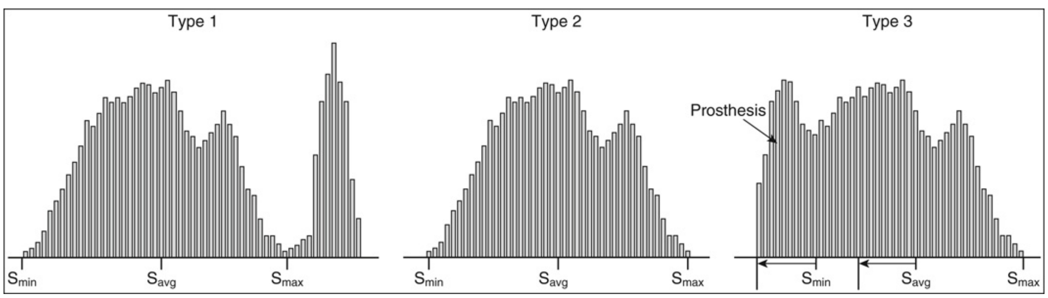


FIGURE 2.4 Histogram analysis types.

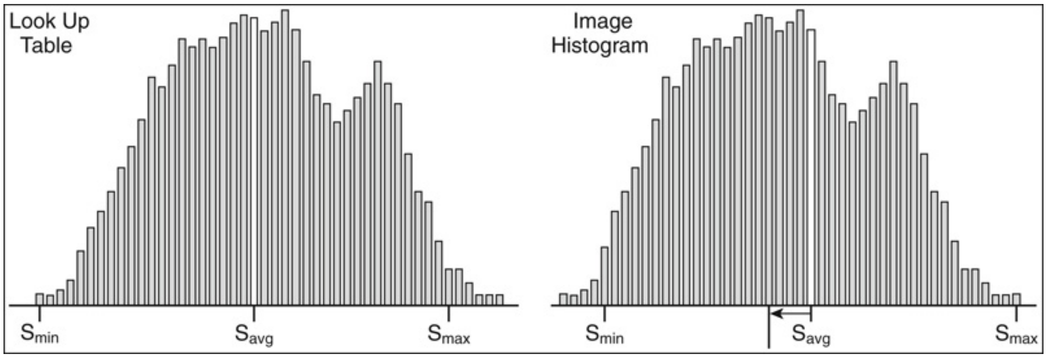


FIGURE 2.5 When rescaling for brightness the image histogram's values are adjusted toward brighter or darker *gray shades* the needed amount to align it with the LUT. The figure demonstrates this occurring for overexposure. The number of *gray shades* between S_{min} and S_{max} has not changed between the two illustrations.

Automatic Rescaling

Included in the computer software is a LUT, or "ideal," histogram for every radiographic projection. These LUTs provide the standard for S_{min}, S_{ave}, and S_{max} that the image histogram is compared and rescaled to. The LUT that is used for a projection is determined when the procedure algorithm is chosen on the workstation. After the histogram analysis is completed and the VOI identified, the pixel values that represent the VOI are sent to the computer for rescaling to the appropriate LUT (also called gradation processing and normalization). Rescaling involves aligning the brightness and somewhat the gray scale range of the image histogram's VOI with that of the selected LUT by applying algorithms to the data.

To rescale for brightness, the computer finds the difference in the S_{ave} values between the image histogram and the LUT, and then makes this

adjustment difference to all values in the VOI, aligning the image histogram values with the LUT values (**Fig. 2.5**). The values in the image histogram are always changed to the standard values in the LUT. If the image histogram was positioned farther to the right than the LUT's histogram, representing a projection in which the remnant beam had more IR exposure than is desired, the algorithm applied to the data would move the obtained values of each pixel toward the left, aligning them with the values in the LUT and brightening up the pixel values before they are displayed. If the image histogram was positioned farther to the left than the LUT's histogram, representing a projection in which the remnant beam had less IR exposure than is desired, the algorithm applied would move the obtained values of each pixel toward the right, aligning them with the values on the LUT and decreasing the brightness of the pixel values before they are displayed.

To rescale the image histogram to the LUT's gray scale, the number of gray shades between S_{min} and S_{max} are adjusted by rounding the values found in the image histogram up or down as needed to align them with the gray scale values in the LUT (**Fig. 2.6**). If the image histogram is wider than the LUT's histogram, representing a projection in which the remnant beam demonstrated lower subject contrast than desired, the algorithm applied to the data would narrow the histogram, decreasing the number of gray scales, which increases the degree of difference between each gray scale and increases the contrast between details. If the image histogram was narrower than the LUT's histogram, representing a projection in which the remnant beam demonstrated higher subject contrast than desired, the algorithm applied to the data would widen the histogram, increasing the number of gray scales, which decreases the degree of difference between each gray scale, decreasing the contrast between details. This process aligns

the gray scale values, but it does not adjust the number of pixels in each gray scale (represented by the *y*-axis on the histogram) to match the LUT. This explains why displayed projections obtained using inadequate kV will demonstrate so many light gray pixels and those obtained without appropriate scatter radiation control practices will demonstrate excessive dark gray pixels even after rescaling.

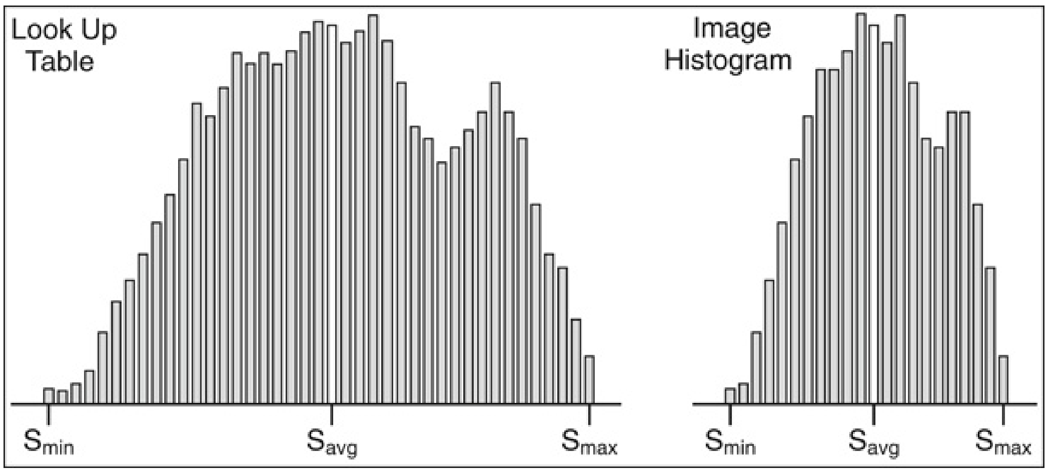


FIGURE 2.6 When rescaling for gray scale the image histogram's values are rounded up or down as needed to align with the number of gray scales in the LUT. The figure demonstrates how the image histogram would change after rescaling to the lower contrast LUT. There will be a widening of the histogram, increasing the number of gray scales used.

Exposure Indicators

Exposure indicators (EIs) are readings that denote the amount of radiation intensity that struck the IR. Although they give an indication of the amount of radiation that the patient was exposed to, they are not measures of dose

to the patient because they do not take into account the energy level of the photons or attenuation. Each digital manufacturer has a method of determining the acceptable EI range and the ideal EI number for their system and provides these numbers to a technologist to use when determining the accuracy of the IR exposure. **Table 2.2** lists different manufacturers' EIs for acceptable exposure for some of the computed radiography and DR systems available. Note that each provides an ideal or average EI and an EI range of acceptable exposures. The ideal EI represents a medium gray value, which usually indicates soft tissue, and because digital systems can successfully rescale a projection that was obtained using two times higher and lower IR exposure than is needed for the ideal EI, the EI acceptable exposure ranges listed will be what the readings would be if the exposure were doubled or cut in half from the ideal (**Fig. 2.7**). The EI expression varies from one manufacturer to another, and technologists are to be aware of those in the facilities where they work.

After the image histogram has been created and analyzed, the EI is read by the computer at the midpoint (S_{ave}) of the defined VOI, and it is displayed on the digital projection. To produce optimally exposed projections, the technologist's goal is to obtain EI readings that are as close to the ideal EI as possible for the digital system used. Projections in which the EI reading is not at the ideal level but within the acceptable range do not require repeating but are evaluated to determine why this has occurred and what technical changes to consider in future projections to bring the EI closer to the ideal. The technical factors are also adjusted when a series of projections are obtained on the same body part and the first projection demonstrates an EI that is not at the ideal exposure. For example, if the AP lumbar vertebral projection demonstrates an EI value that is in the EI acceptable range but is closer to the far ends of underexposed or

overexposed, this projection is not repeated, but the technique is adjusted for the AP oblique and lateral projections prior to exposure to bring them to the ideal exposure. See the section on IR exposure later in this chapter for information on how to adjust technical factors when there is no indication of a histogram analysis error and the EI number is not ideal or is outside the EI range. Because the EI is derived from the histogram, any error that causes a histogram analysis error will also affect the accuracy and usefulness of the obtained EI reading.

TABLE 2.2

Siemens YSIO DR	Exposure index (EI)	125-500 range	250 ideal	Under exposed <125	Over exposed >500

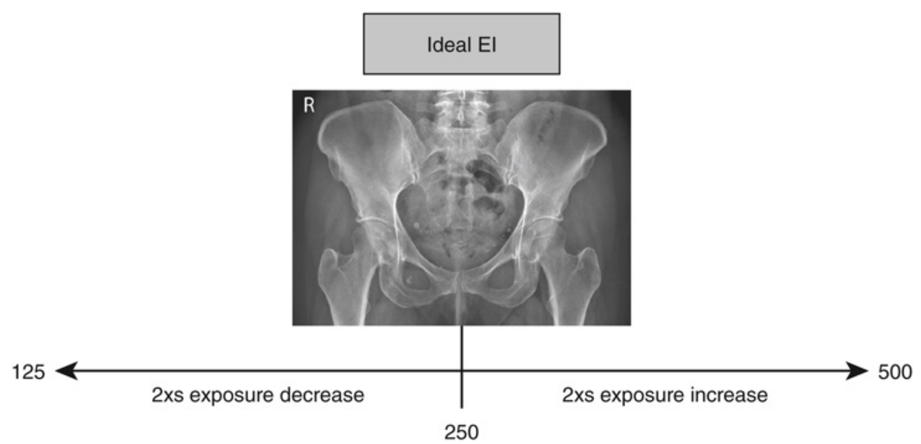


FIGURE 2.7 Exposure indicator parameters for the Siemens YSIO DR system.

Histogram Analysis and Exposure Indicator Errors

Histogram analysis errors produce poor quality projections because the image histogram's shape does not match the histogram analysis type used, resulting in the computer not accurately identifying the VOI from the

undesirable data and resulting in some or all of the undesirable data being sent to the LUT for rescaling. Displayed projections with histogram analysis errors also demonstrate EI errors and can be too light or too dark or have excessive contrast or gray scale. Even though the displayed projections from these errors demonstrate quality issues that are similar to those seen when the technical factors are incorrectly set, they are due to the computer's inability to correctly decipher and modify the data to the LUT and not because of technical factors. Some projections obtained with histogram analysis errors can be windowed to be made acceptable, but because the windowing range is narrowed when projections are obtained with histogram analysis error, many will require repeating. To produce optimal projections, the technologist needs to provide the computer with what it needs to be able to accurately analyze and work with the data. The most common reasons for histogram analysis and associated EI errors are listed in **Table 2.3**.

FIGURE 2.8 The AP cervical projection demonstrates direct exposure areas lateral to the cervical vertebrae, which indicates that a type 1 analysis should be used for this projection so this area is not included in the VOI during rescaling. If the projection was processed using a type 2 histogram analysis instead of type 1, which assumes that there will be no background tail on the histogram's right side, as the computer is scanning the image histogram

from the right to identify S_{max}, it will not eliminate the tail from the VOI. This results in the tail section being included in the VOI, a wider dynamic scale, and the S_{ave} (EI) being located at a darker shade value on the *x*-axis of the image histogram than is accurate for soft tissue. Since the shade value of soft tissue (medium gray) is to be placed at S_{ave} on an accurate image histogram and this AP cervical vertebrae projection will have a darker shade at this location, when the image is rescaled to the LUT, the darker S_{ave} value will be aligned with the LUT's S_{ave} (which is the shade of soft tissue) and all other values will be equally adjusted, overcorrecting toward the brighter shade values and making the displayed image brighter than desired.

FIGURE 2.9 The AP lumbar vertebrae projection in **Fig. 2.9** was processed using a type 1 histogram analysis, which assumes that there will be a background tail on the right side instead of a type 2, which assumes no tail. As the computer is scanning from the right to identify S_{max}, there will be no tail on the image histogram for the computer to disregard, so it will move into the VOI and exclude some of this data from being sent to computer for rescaling. This

will cause S_{ave} to be located at a lighter shade value on the image histogram than that which represents soft tissue. When the image is rescaled to the LUT, the lighter S_{ave} value will be aligned with the LUT's S_{ave}, and all other values will be equally adjusted, overcorrecting toward the darker densities and resulting in the displayed image being too dark.

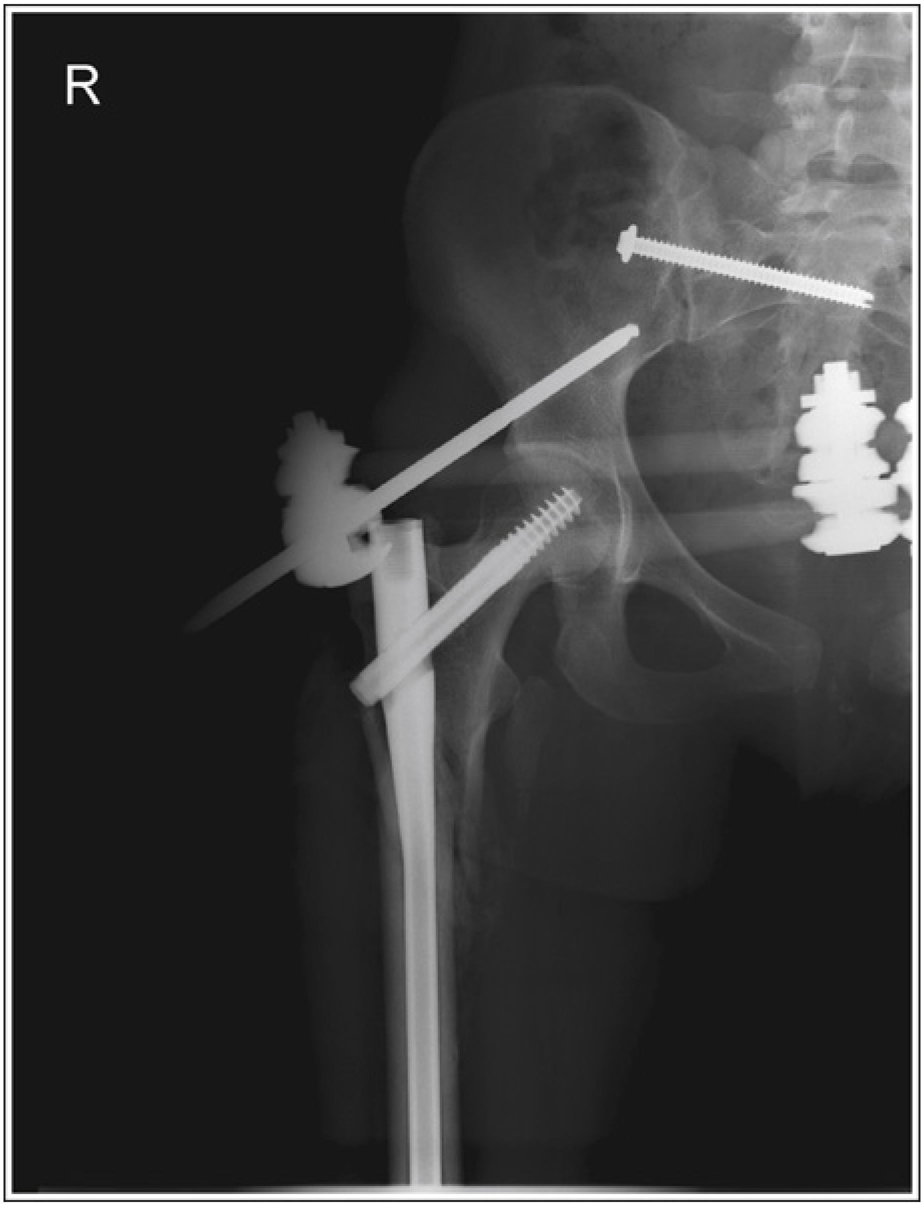


FIGURE 2.10 The AP hip projection was processed using a type 1 histogram analysis, which assumes a background tail on the right side that is disregarded when the computer locates S_{max}, but it does not assume a white bolus on the left side when it is locating S_{min} as required for this hip projection. As the computer scans from the left to identify S_{min}, it will not disregard the white bolus that represents the

screws and prostheses that are in the hip. This will result in the white bolus section being included in the VOI, a wider dynamic scale, and the S_{ave} being located at a lighter shade value on the *x*-axis of the image histogram than is accurate for soft tissue. Since the shade value of soft tissue is to be placed at S_{ave} on an accurate image histogram and this AP hip projection will have a lighter shade at this location, when the image is rescaled to the LUT the darker S_{ave} will be aligned with the LUT's S_{ave} and all other values will be equally adjusted, overcorrecting toward the darker shade values and making the displayed projection darker than desired.

FIGURE 2.11 The lateral cervical vertebral projection was obtained with poor CR centering and collimation, which resulted in a large portion of the upper thorax being included on the projection. The image histogram will record the bright value that is the upper thorax on the left side of the VOI. Since the LUT for the lateral cervical vertebrae will not include this large white area and there will be no indication for it to be disregarded in the histogram analysis process,

it will be included in the VOI and sent to the computer for rescaling. This will result in S_{ave} being located at a lighter shade value on the image histogram. When the image is rescaled to the LUT, the lighter S_{ave} value will be aligned with the LUT's S_{ave} and all other values will be equally adjusted, overcorrecting toward the darker densities and resulting in the displayed image being dark.

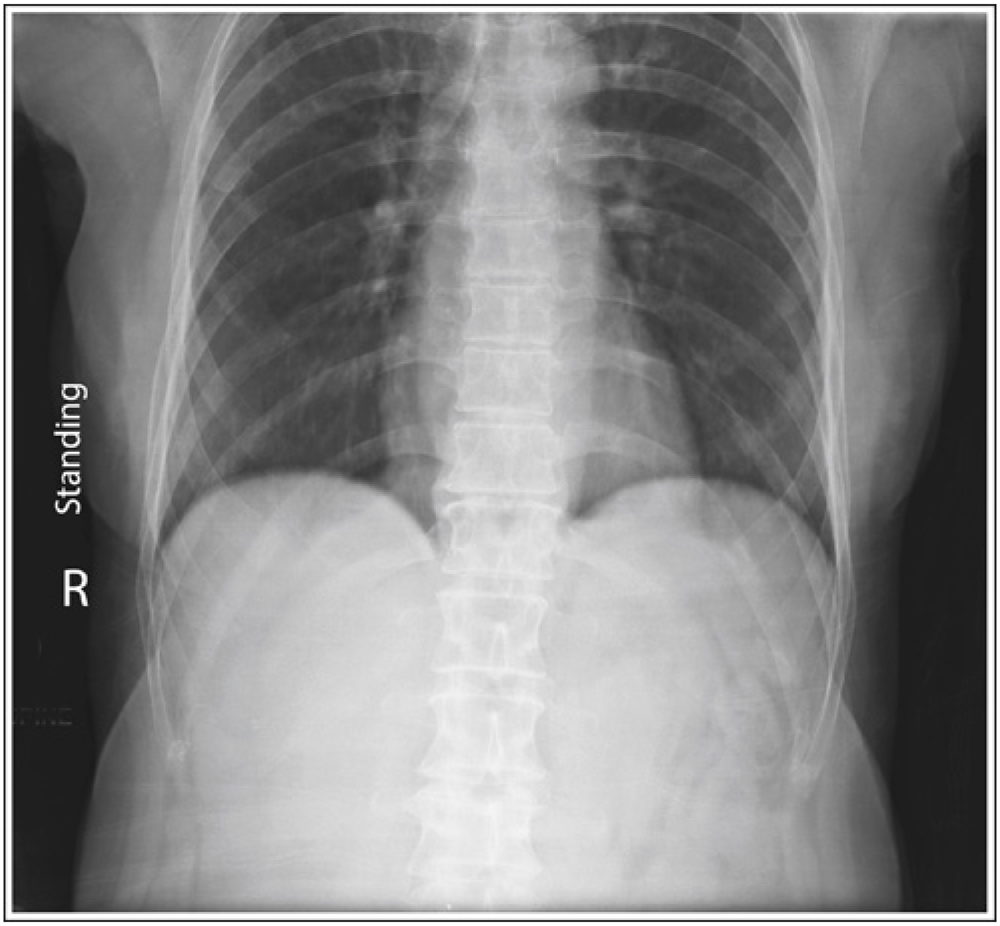


FIGURE 2.12 AP upright abdomen projection that was centered too high and obtained after a full inspiration. The resulting image histogram included the dark chest densities on the right side and included them in the VOI. This resulted in S_{ave} being located at a darker shade value on the image histogram. When the image is rescaled to the LUT, the darker S_{ave} value will be aligned with the LUT's S_{ave}, and all other values will be equally adjusted, overcorrecting toward the lighter densities and resulting in the displayed image being too light at the VOI.

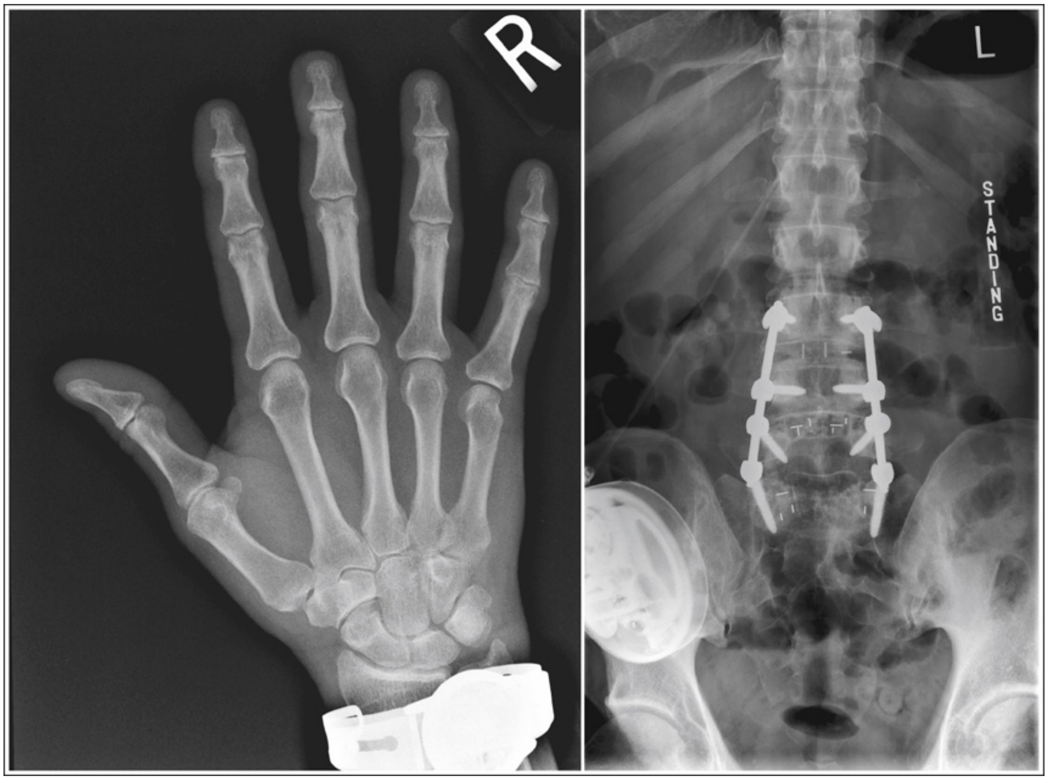


FIGURE 2.13 PA hand projection that includes a watch artifact within the collimation field and an AP lumbar vertebrae that includes internal artifacts in the right ilium and vertebrae. The image histograms for these projections will include the artifacts on the left sides and within the VOI unless a type 3 histogram analysis, which tells computer to disregard the large white bolus at left, is used. This will widen the image histogram and eschew the S_{ave} toward a lighter density. When the projections are rescaled, they are overcorrected toward the darker densities, displaying a darker image.

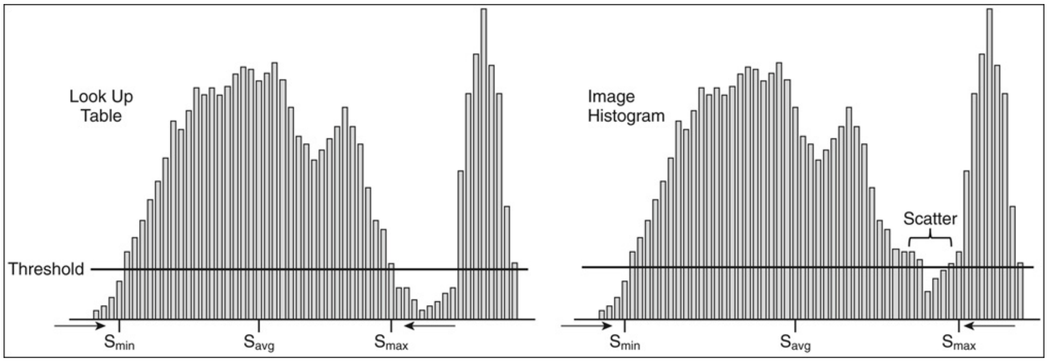


FIGURE 2.14 Q. B. Carroll in "Radiography in the Digital Age" states that scatter radiation fogging causes the tail spike to widen and increases the number of pixels that represent the dark gray values of scatter between the tail spike and S_{max}. As long as these values do not exceed the threshold pixel number designated to represent scatter, they will not be included in the VOI and thus the computer will be able to properly identify the S_{max} landmark and prevent a histogram analysis error. If the threshold is exceeded due to excessive scatter reaching the IR, the scatter is included in the VOI and the image histogram will be positioned farther to the right than the LUT's histogram.

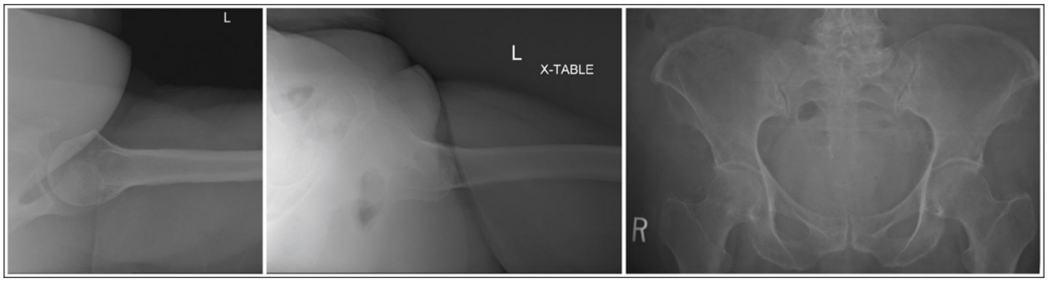


FIGURE 2.15 If excessive scatter radiation is present, causing an increase in pixel numbers that exceeds the threshold, the computer is unable to eliminate them from the VOI, causing a widening of the image histogram toward the right and eschewing S_{ave} toward a darker shade value. During the rescaling process the projection will be aligned for brightness and the number of gray shades between S_{min} and S_{max} by rounding the gray shade values as needed to the LUT, but because the rescaling process is unable to adjust the number of pixels in each gray scale to match the LUT, the displayed image will demonstrate excessive dark gray pixels even after rescaling. This darkness can only be improved upon with scatter control practices (e.g., collimation, grid).

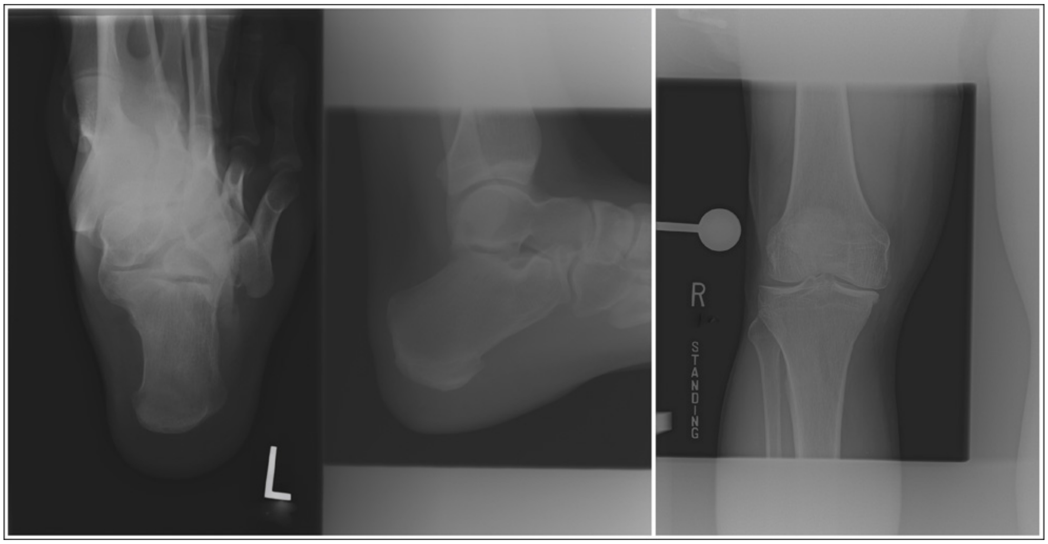


FIGURE 2.16 When two or more exposed fields are treated as one image when using computed radiography due to the collimation borders being overlapped or not included, the different projections are not rescaled separately but are treated as one projection and the light densities outside the collimated borders are included in the image histogram's VOI, causing S_{ave} to be eschewed to a lighter density. When the projections are rescaled, they are overcorrected toward the darker densities, displaying darker projections. The same happens when one of the collimated borders is not demonstrated, as shown in the AP knee projection.

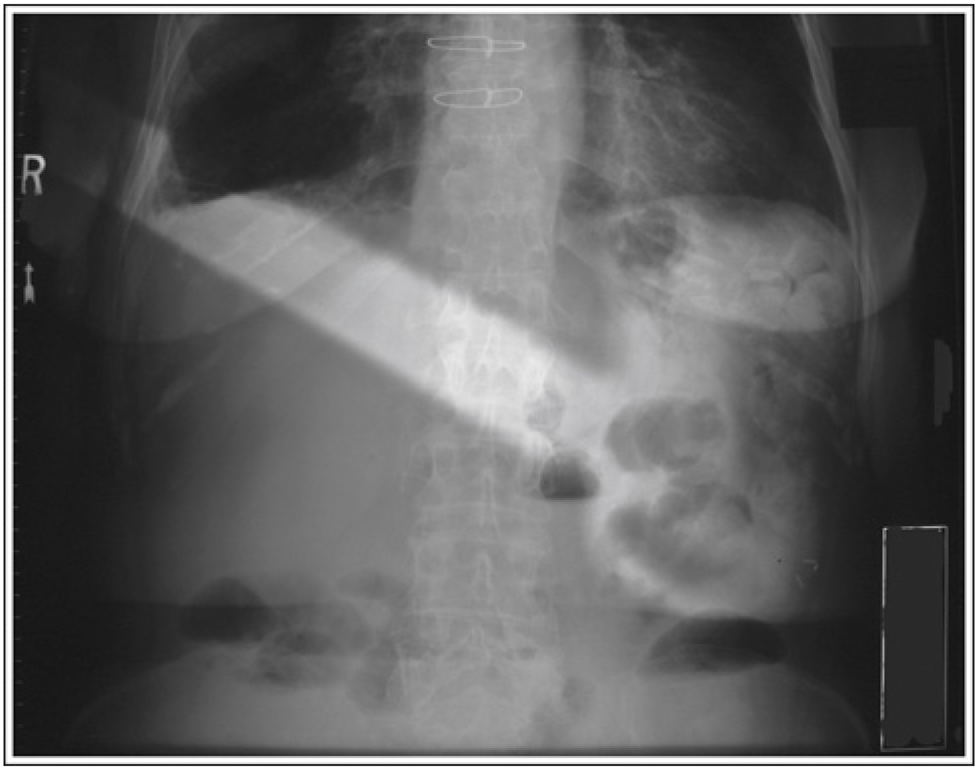


FIGURE 2.17 An AP abdomen projection that was exposed on a computed radiography IR that was left in the imaging room while additional images were performed or was not erased after 48 hours of nonuse will collect scatter and background radiation. This fogging adds exposure to all areas of the IR and will be treated similar to scatter radiation, as described in Figs. 2.14 and 2.15 when a projection exposed on the IR has been rescaled. The bright streak that runs through the center of the projection is part of the wheelchair that the IR was resting against when it was left in the room while other exposures where performed. The abdominal structures included in the bright area demonstrate acceptable quality and suggest

how the projection would have looked if the fogging had not occurred.

TABLE 2.3

CR, Central ray; *DICOM*, digital imaging and communications in medicine; *IR*, image receptor; *LUT*, lookup table; *VOI*, values of interest.

Quality Image (Resolution)

The quality of the displayed radiographic projection is defined by how well the details in the VOI have been resolved (seen as separate and distinct from each other). When determining the quality of the resolution, the projection is evaluated for how visible the details are, as defined by the factors of brightness, contrast, and noise, and how recognizable the details are as defined by the factors of spatial resolution, magnification, and shape distortion (**Table 2.4**).

Brightness

Although brightness is rescaled to the LUT before being displayed and can be adjusted through postprocess windowing at the display monitor, first it must exist in the remnant image. This inherent brightness level is based on the radiographic technique used to produce the procedure independent of the display brightness and is ideal when the VOI is demonstrated using a broad range of different intensities. *Intensity* refers to the total quantity of x-ray photons that expose the patient and IR. The controlling factor for intensity and IR exposure is milliampere-seconds (mAs), with factors such as kV, SID, OID, collimation, and grids affecting it in smaller degrees.

Contrast

Contrast is the ratio or percentage of difference between two adjacent brightness levels. If the ratio or percentage difference is greater between the two details, the contrast is high (**Fig. 2.19**), and if the difference is less between the two details, the contrast is low (**Fig. 2.20**). A high contrast projection appears more black and white, and a low contrast projection is gray overall. If the contrast difference is not great enough between the details, they will not be distinguishable from each other and will appear as one detail. An intermediate contrast range is ideal. When evaluating the contrast in a projection, it is important to compare the contrast of the anatomical structures in the VOI with each other and not to compare the anatomy to the black raw data that is outside the anatomy. DR provides superior contrast resolution because of the ability of the IR to discern a 1% difference in subject contrast, and because of the extensive dynamic range (gray scale) that is available to display the image. The degree of contrast resolution presented on images is determined by the quality of the subject contrast represented in the remnant beam, the dynamic range available, and the processing algorithms applied to the image data before they are displayed. **Box 2.1** describes the contrast differences that are demonstrated for common conditions.

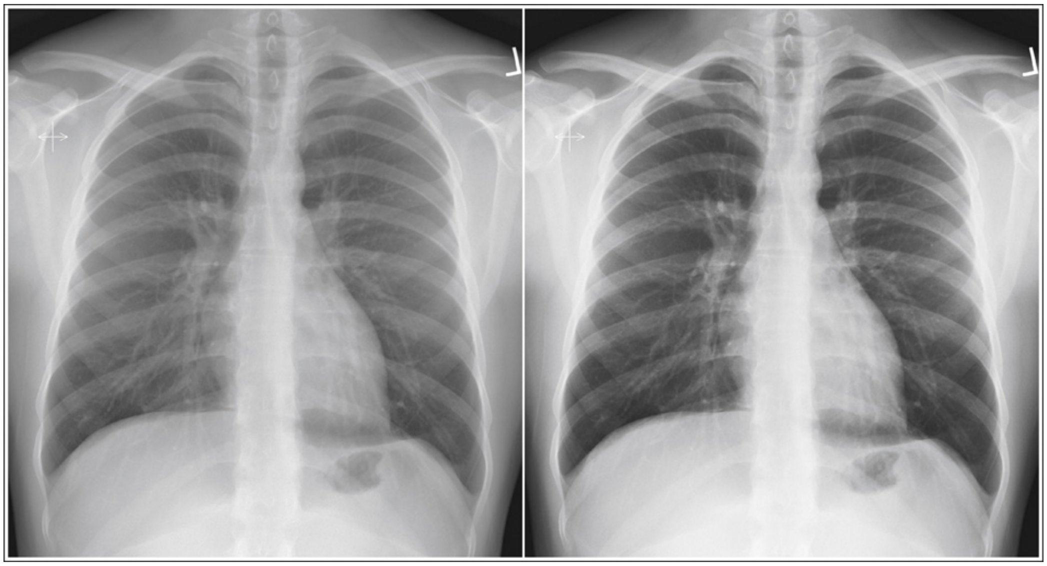


FIGURE 2.18 A low contrast chest projection will demonstrate increased contrast if it was processed under a high contrast hip projection. Because the hip LUT has a shorter dynamic range than the chest LUT, during rescaling the image histogram of the chest will be narrowed to align with the hip LUT and result in the chest projection being displayed with higher contrast.

FIGURE 2.19 AP foot projection with high subject contrast.

TABLE 2.4

Quality Image (Resolution)

Visibility of details. When there is no histogram analysis error and the visibility of detail factors affecting the EI number, subject contrast visualization, quantum noise, and scatter fogging have been optimally set: • EI number is ideal for an optimal projection and two times above or below the ideal for an acceptable projection. • Contrast resolution on the displayed projection is such that every anatomical detail in the VOI is depicted as a particular shade of gray, from light to dark, and no part of it is completely white or pitch black. • Signal to noise ratio (SNR) is high. **Spatial resolution (detail sharpness).** When the spatial resolution factors affecting detail sharpness have been optimally set: • All of the required details are visualized on the projection. • The details on the projection are individual and distinct from each other (sharp).

EI, Exposure index; *VOI*, values of interest.

FIGURE 2.20 AP foot projection with low subject contrast.

Subject Contrast

Subject contrast is the amount of intensity in the remnant beam that demonstrates the degree of differential absorption resulting from the differing absorption properties of the body structures (atomic density,

atomic number, and part thickness). It is demonstrated on the displayed projection with differing gray shades. Kilovoltage peak (kVp) is the technical factor that determines the energy and penetrating ability of the x-ray photons produced and is the controlling factor for differential absorption and the subject contrast represented in the remnant beam. For each body structure, there is an optimal kVp to use that provides appropriate penetration and differential absorption of all the tissues in the VOI, as well as provides a balance between patient dose and the amount of scatter that is directed toward the IR. The optimal kVp level to use is provided for each projection in the following procedure chapters. At optimal kVp, there is at least partial penetration through all tissues to be demonstrated on the projection. *As one is adjusting kVp from optimum because of increased thickness or an additive disease process, it should be noted that if the kVp is set above 80 kVp, absorption of the photons will no longer take place in soft tissue and if set above 120 kVp will no longer happen in bone.* This is because photoelectric interactions will no longer occur in these structures at this high kVp, reducing subject contrast on the projection.

FIGURE 2.21 AP pelvis projection on patient with high subject contrast.

Box 2.1 Contrast Differences Demonstrated on Common Conditions

- **Patients who are in good physical shape, with strong muscles, low fat content, and dense bones usually display the highest subject contrast (Fig. 2.21).**
- **Patients whose bodies have deteriorated because of disease or age and obese patients ordinarily display less subject contrast because their muscles have lost strength and have become the consistency of fat. On an image of this patient, subject contrast is low because the densities representing fat and muscle are more alike (Fig. 2.22).**

- Images of bony structures that have lost minerals and are less dense because of disease appear darker gray on images rather than lighter gray, blending in more with the surrounding structures and demonstrating lower subject contrast (Fig. 2.23).
- Patients who have retained fluid because of disease or injury display lower subject contrast because the fluid surrounds the body tissues and causes their tissue densities to become more alike (Fig. 2.24).
- The bones of infants and children are less dense and more porous than adult bones, resulting in lower subject contrast being demonstrated between the bone and soft tissue in children's images compared with adults' images (Fig. 2.25).

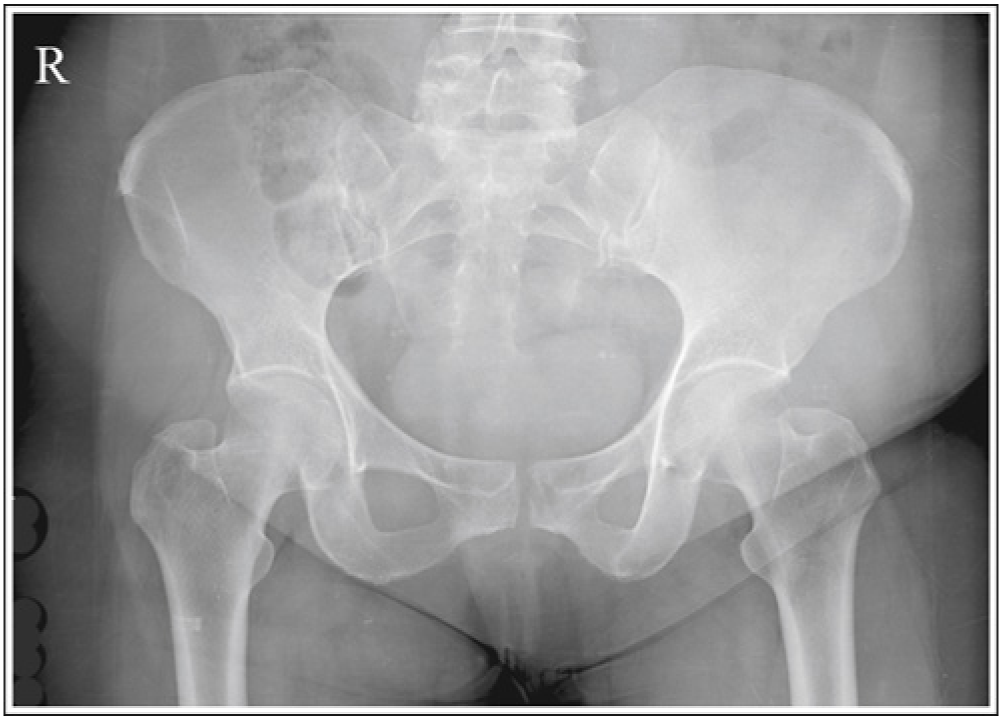


FIGURE 2.22 AP pelvis projection on patient with low subject contrast.

FIGURE 2.23 Lateral ankle projection demonstrating low subject contrast caused by a destructive disease.

Penetration

A bony structure that has been adequately penetrated demonstrates the cortical outlines of the densest and thickest bony structures of interest, whereas an inadequately penetrated bony structure would not demonstrate all of the bony structures of interest. Note that if a transparency were laid

over the bottom pelvis in **Fig. 2.26** and an outline of the bony structures drawn on the transparency, with lines made only where the cortical outlines of the bone were clearly visible, the cortical outlines of the sacroiliac joints and the acetabulum would not be drawn. If the cortical outlines of the structure of interest are not seen an increase in kV is required. When an organ with contrast medium is not adequately penetrated (**Fig. 2.27**), the information is limited to the edges of the anatomy and does not visualize information within the organ. It should be noted that no amount of adjustment in mAs will ever compensate for insufficient kV.

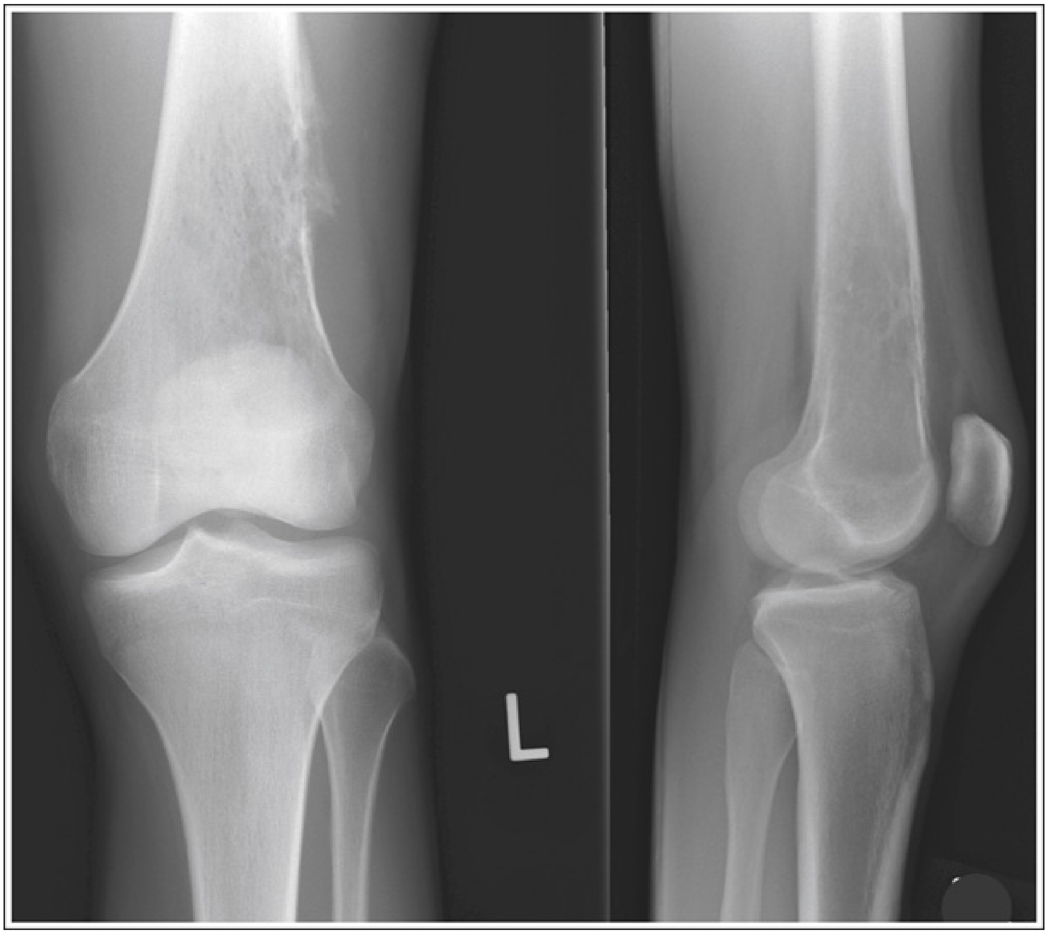


FIGURE 2.24 AP and lateral knee projection that demonstrates fluid around the knee joint that affects subject contrast.

FIGURE 2.25 AP knee projection on pediatric patient that demonstrates low subject contrast.

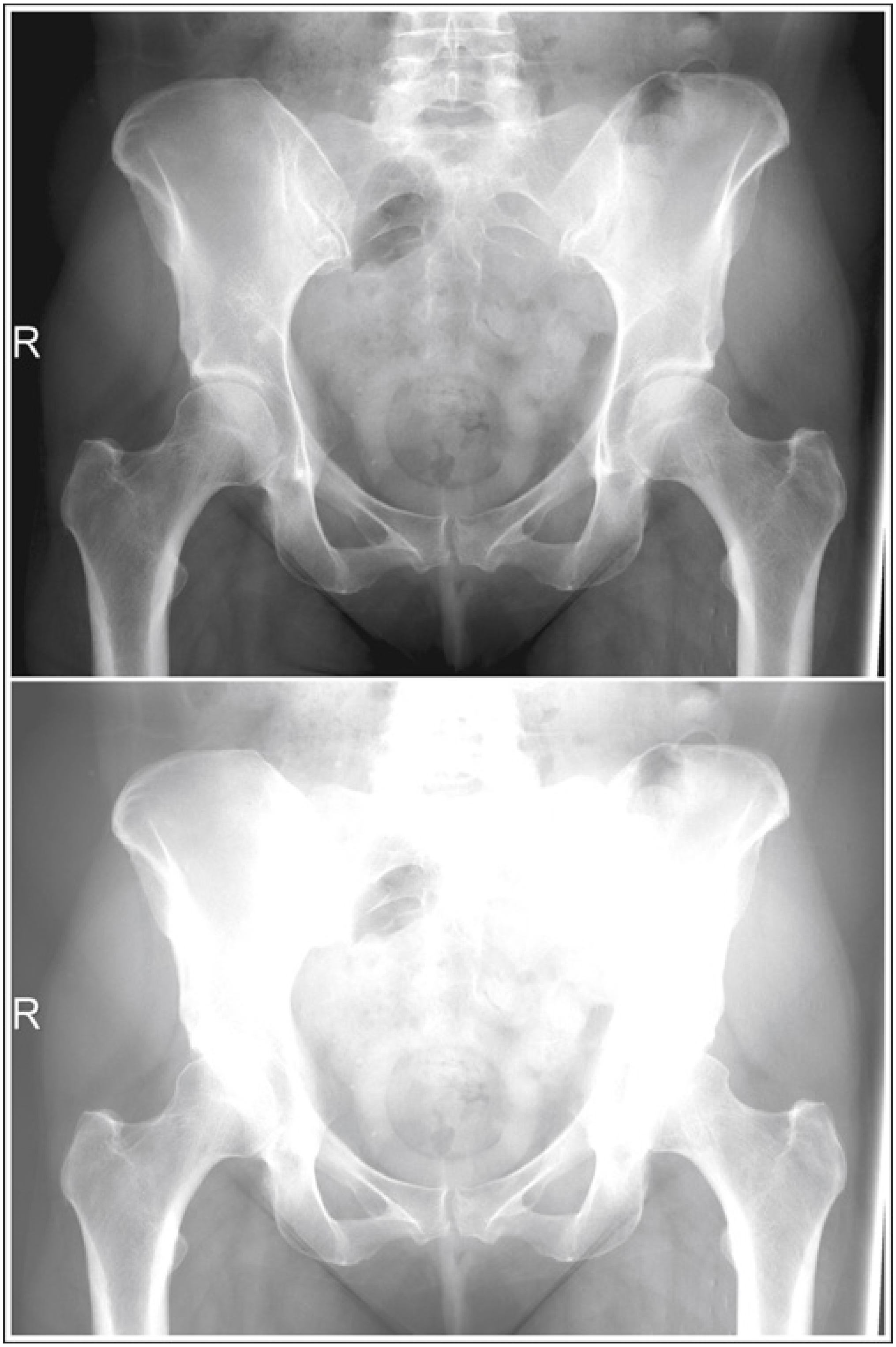


FIGURE 2.26 Accurately penetrated *(top)* and underpenetrated *(bottom)* AP pelvic projection.

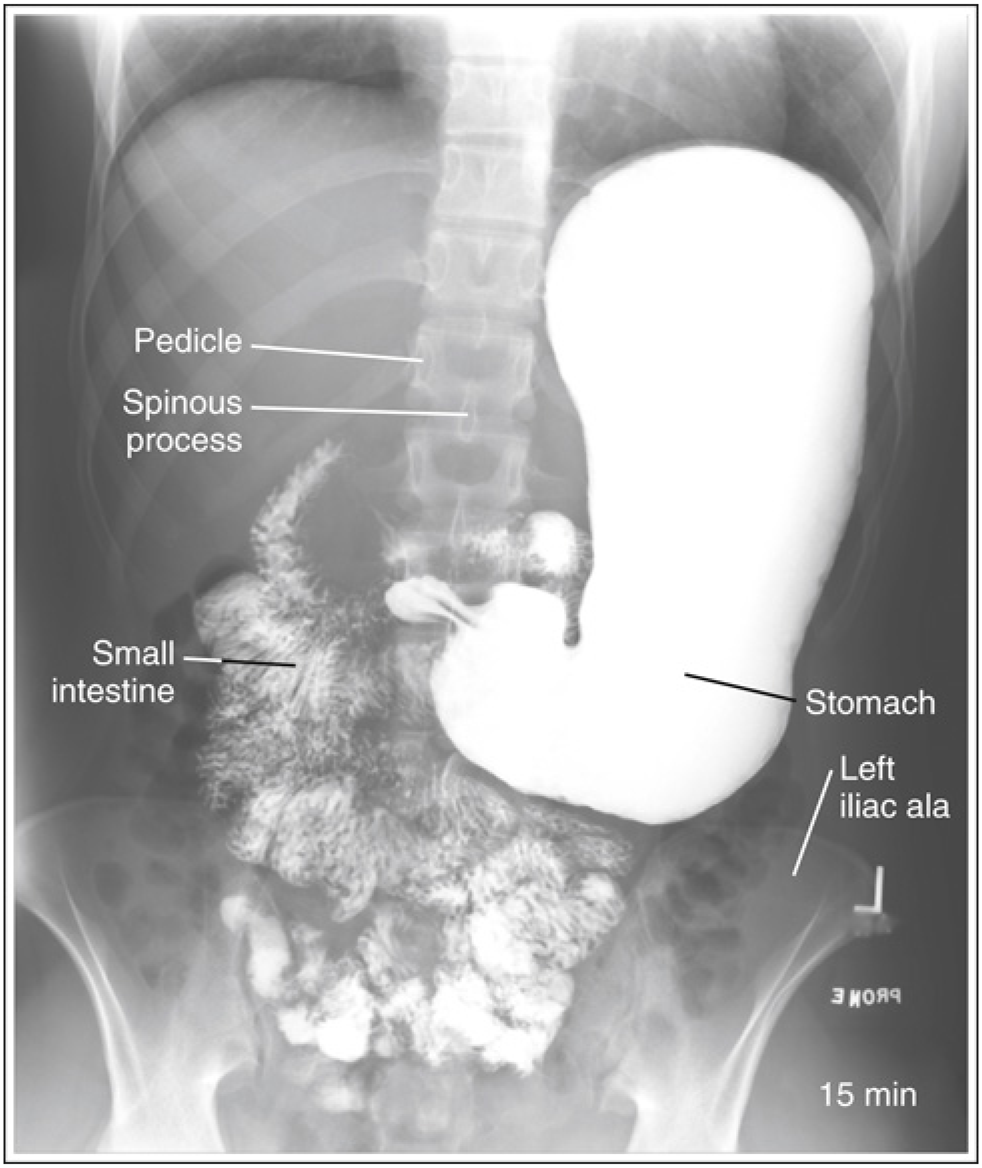


FIGURE 2.27 PA small intestinal projection demonstrating contrast media in the stomach that has not been fully penetrated.

Saturation

Saturation is demonstrated on a projection as a loss of contrast resolution where some or all of the structures in the VOI demonstrate a pitch-black shade (**Fig. 2.28**). It is caused by overwhelming the digital system with

electronic signals due to using extreme exposure. Details that have been saturated on a projection cannot be properly analyzed. Windowing cannot restore the saturated areas.

Noise

Noise is defined as any nonuseful input to the projection that will interfere with the visibility of the VOI. Artifacts, scatter radiation, quantum mottle, and electronic noise are examples of common factors that cause noise.

Scatter Radiation

Scatter radiation originates from large body parts, large field sizes, and high kVp levels. It is produced when primary photons interact with the tissue's atomic structure and with the imaging tabletop or other objects when the light field is not collimated to 0.5 to 1 inch from the skin line and are scattered in a direction that differs from the primary photon's original path. They are destructive because they add an evenly distributed blanket of exposure, also known as fog, across the projection, lowering the visibility of the subject contrast as the distinct gray shades of adjacent details blend with each other.

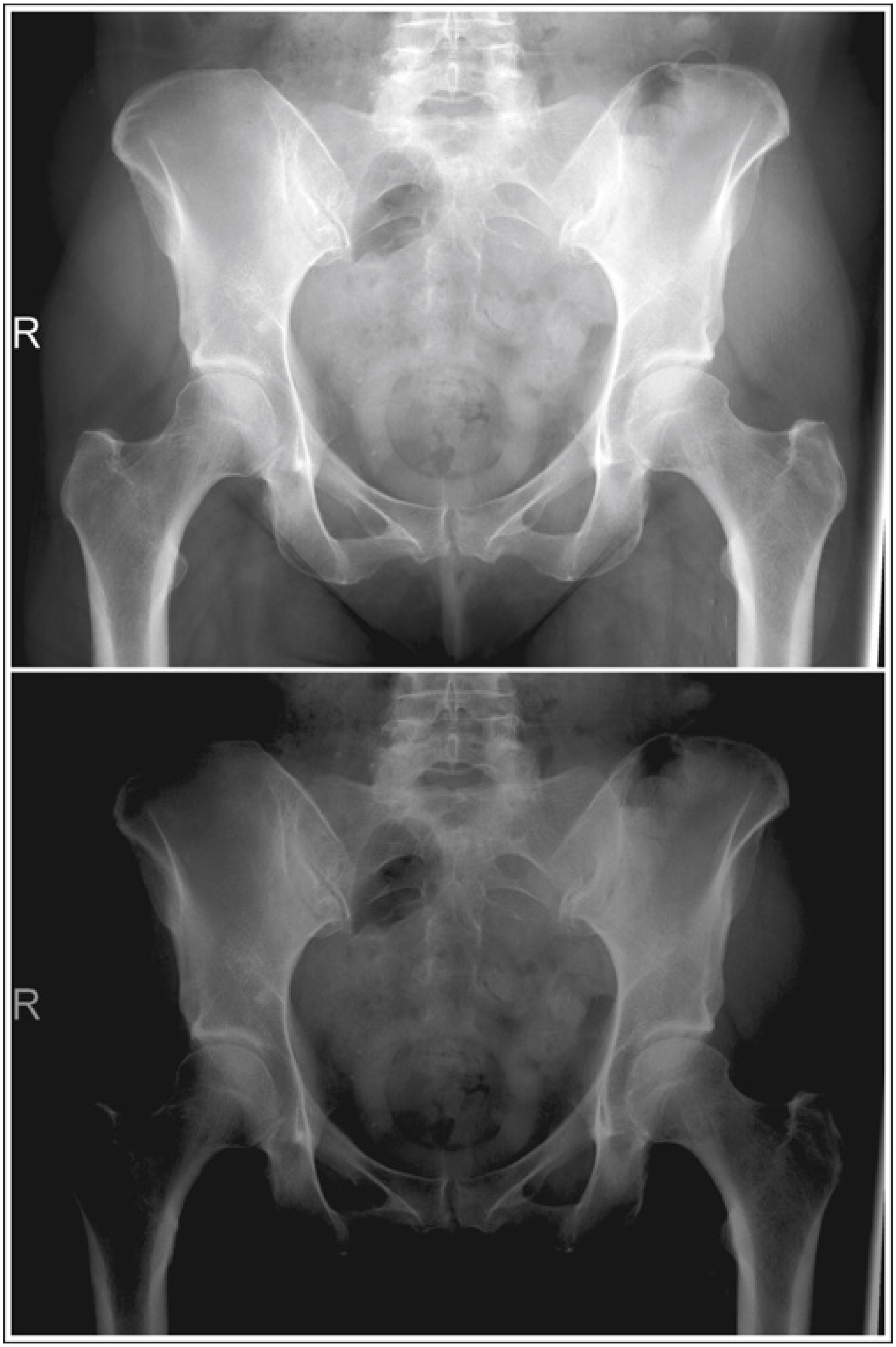


FIGURE 2.28 Accurately exposed *(top)* and overexposed *(bottom)* AP pelvis projections.

As the thickness of the body part increases, more scatter is generated and the ratio of useful signals compared with the scatter noise signals decreases, meaning that scatter will make a greater contribution to the total IR exposure with increasing thickness (**Fig. 2.29**). The type of tissue being imaged also affects scatter production. Structures that demonstrate greater atomic density will result in more scatter production. For example, with the same patient thickness when air is present, as with a chest projection or abdomen projection on a patient with a large amounts of bowel gas, the scatter production in these body structures will be less if the thickness was mostly made up of air instead of soft tissue and bone. This is because air has very few atoms for a Compton interaction to take place with, and less scatter is produced.

At high kVp levels, the scatter radiation that is produced is more noticeable on the projection because it is directed in a narrower angle with the IR and is more difficult for grids to eliminate. With kVp determining the penetration and differential absorption of the image details, using kVp to control scatter is not a feasible method of reducing its effect on the projection. The only effective means of controlling the amount of scatter radiation that reaches the IR is to reduce the amount of exposed tissue by increasing collimation and by using a grid to absorb the scatter radiation. The more collimation is increased and the higher the grid ratio that is used, the greater the scatter cleanup and visibility of detail improvement. Flat contact shields made of lead can also be used to control the amount of the scatter radiation that reaches the IR by eliminating scatter produced in the imaging tabletop from being scattered toward the VOI on the IR. When the anatomic structures being examined demonstrate an excessive amount of scatter fogging along the outside of the collimated borders (e.g., the lateral lumbar vertebrae), place a large flat contact shield or the straight edge of a

lead apron along the appropriate border. This improves contrast resolution (**Fig. 2.30**).

FIGURE 2.29 The first AP pelvis was obtained on a patient with an AP measurement of 24 cm, and the second AP pelvis was obtained on a patient with an AP measurement of 43 cm. The second pelvis demonstrates a decrease in SNR because of excessive scatter radiation that was included in the image histogram's VOI. Scatter is more evident with larger patients because the ratio between useful signals compared to scatter noise signals decreases.

Quantum Noise

Quantum noise is demonstrated when the amount of exposure reaching the IR is too low, causing the number of photons hitting the IR to be low and the random distribution of the photons to be seen on the projection as graininess or a random pattern superimposed on the projection (**Fig. 2.31**). It can obscure borders, affecting edge discrimination, and can obscure underlying differences in shading, affecting contrast resolution. The

postprocessing technique of windowing will only make the quantum noise more visible. The only way to decrease quantum noise is to make a change that will result in an increased number of photons reaching the IR, with the most direct change being to increase the mAs and/or kV.

Signal to Noise Ratio

The *signal to noise ratio (SNR)* is used to compare one exposure to the next and is defined as a ratio between the desired signals and the undesired signals that are used to create an image. The desired signals represent remnant beams of the VOI on the projection, and the noise includes the scattered radiation, quantum mottle, and electronic static represented on the image. The higher the SNR, the more desired to undesired signals that were used.

Contrast Resolution

Contrast resolution is the ability of an imaging system to distinguish between details by displaying them with different gray shades. Contrast resolution is superior when the imaging system is able to distinguish between details that are very close in attenuation coefficients. The number of gray shades available (dynamic range) to display the image for a digital system is inherent and determined by the bit depth of the pixels.

Bit Depth and Dynamic Range

The maximum range of pixel values that a digital system can store is expressed as the bit depth of the pixels. Digital systems currently manufactured have pixels that are 14-bit (2^{14}) deep, allowing 16,384 potential values to be stored for each pixel. These values are used to define the gray shades that are displayed on the monitor. Because the remnant

beam contains only about 1024 different gray levels and the human eyes are only capable of distinguishing about 32 (2^5) different gray shades, the full information obtained by the system during an exposure (raw data) does not need to be displayed. Instead, the predetermined system software indicates the range of values that will be made available to display images. This system range is called the dynamic range (gray scale) of the digital system. For each procedure, there is a procedural algorithm that indicates the dynamic range and average brightness levels for the computer to use when displaying the procedure. These are embedded in the LUTs that are used when the histogram is automatically rescaled to optimize the anatomic structures for that procedure.

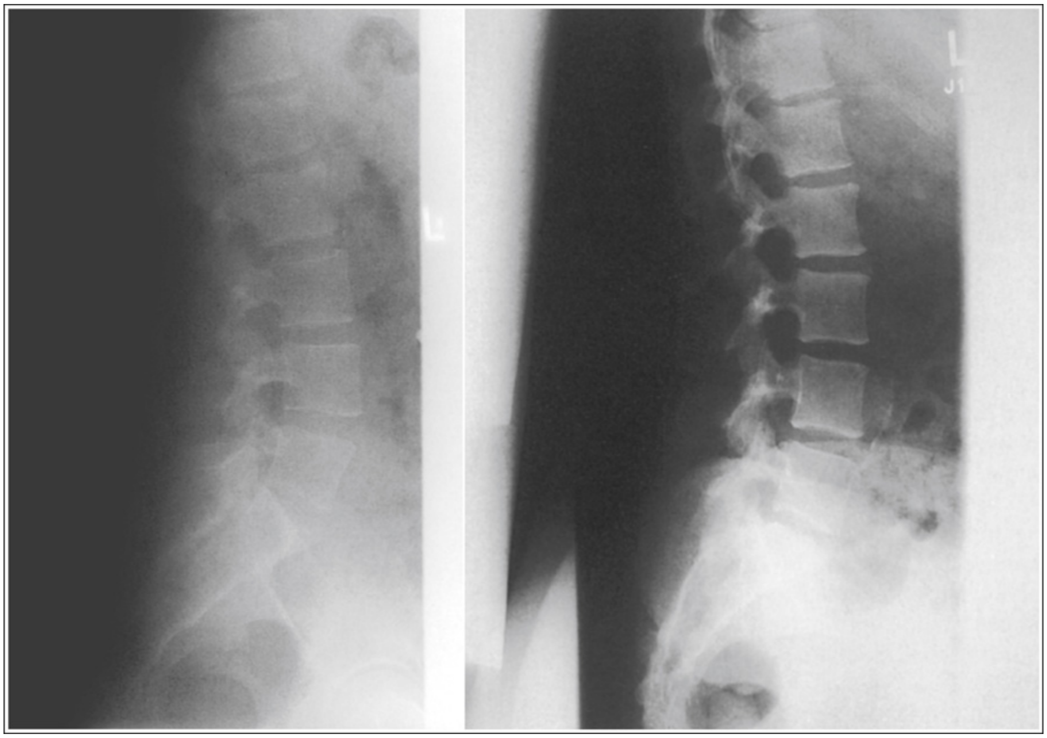


FIGURE 2.30 Flat contact shields made of lead placed at the edge of the collimation field can be used to control the amount of scatter radiation that reaches the IR by eliminating scatter produced in the table from being scattered toward the VOI on the IR. The first lateral lumbar vertebral projection was obtained without using the contact shield, and the second projection was taken with a lead contact shield placed against the posterior edge of the collimator's light field. Note the improvement in visualization of the lumbar structures using a contact shield.

FIGURE 2.31 An underexposed AP skull projection obtained with a CareStream CR and demonstrating quantum noise and an EI number of 1400. If the original mAs was increased by a factor of 4, the EI would be raised by 600 points to 2000, which is the ideal for the imaging system.

Exposure

The total IR exposure includes x-rays from the penetrating primary and scattered secondary x-rays. When either of these types of x-rays are reduced or increased, the IR exposure changes, respectively. As long as at least some amount of primary x-rays are penetrated through all of the tissues, an under-

or overexposed projection that is off by a factor of 2 can be rescaled and does not need repeating (Figs. **2.32** and **2.33**). Tables **2.5** and **2.6** list how to identify, and the causes and adjustments to make for, under- and overexposed projections. The windowing range is narrowed when projections are obtained that are outside the acceptable exposure range.

Other Exposure-Related Factors

A projection will seldom need repeating because of failure to make adjustments from the procedural routine for the following exposure-related factors, unless the change has caused significant overexposure or underexposure or a procedural error occurred. Projections that do require repeating will demonstrate the same characteristics as described for identifying overexposure and underexposure. In most cases, the exposure adjustments should be made for these changes before the projection is obtained, with the goal being to keep the EI number as close to the ideal as possible.

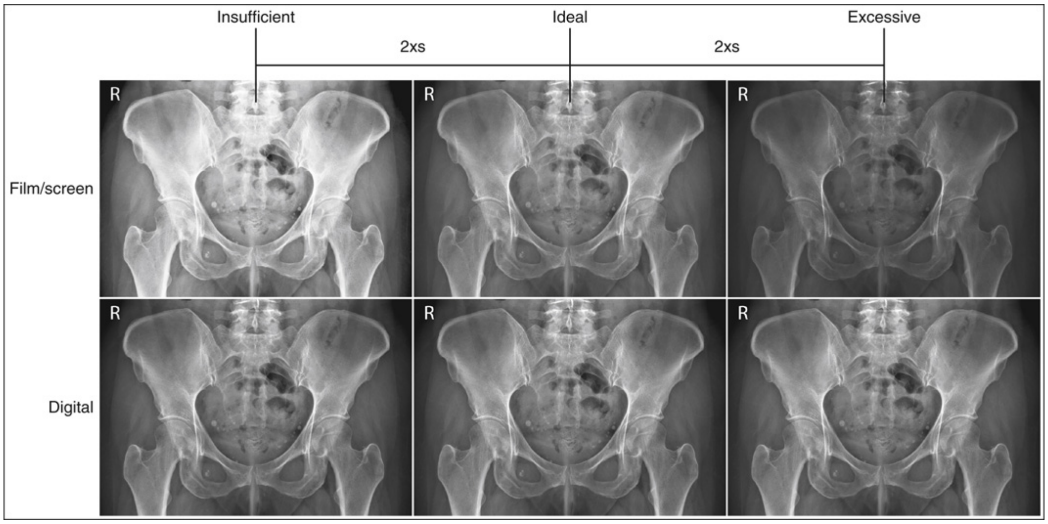


FIGURE 2.32 In the first row, the ideal center pelvis projection has been copied and windowed to demonstrate how the remnant beam looks when optimal kVp is used and the mAs is set within the acceptable exposure range. The second row demonstrates how the projections in row 1 would be seen after rescaling. Underexposed or overexposed projections that are within this 400% window do not have to be repeated. It is when the exposure falls outside this window that a repeat is warranted. If a projection is obtained that appears to look like those to the right or left of the center projection in the first row, its cause is not due to IR exposure but instead to a processing issue.

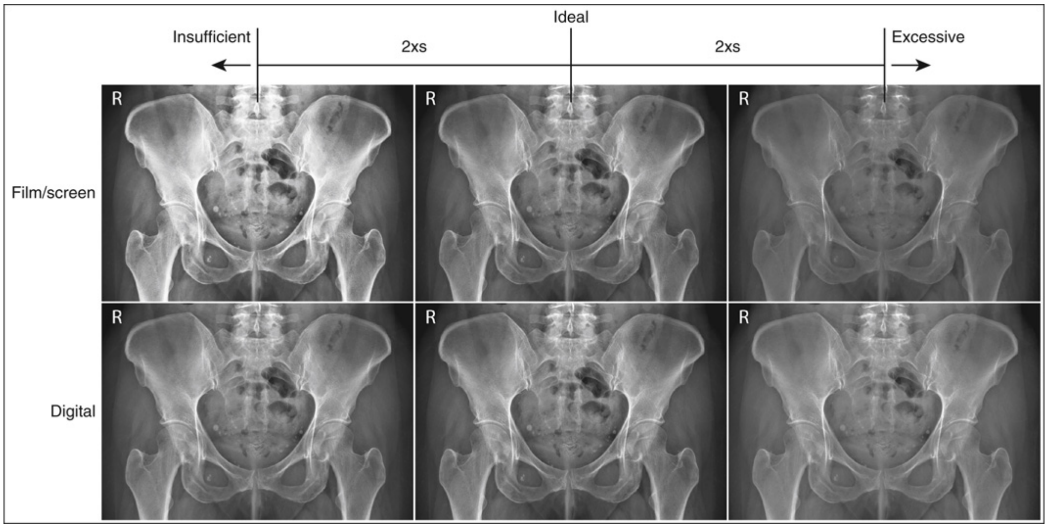


FIGURE 2.33 In the first row the ideal center pelvis projection has been copied and windowed to illustrate how the pelvis projection using film/screen will look if the kVp is set 15% (2xs) above and below optimal and yet still within the acceptable exposure range. The second row demonstrates how the projections in row 1 are seen in digital after rescaling. Underexposed or overexposed projections that are obtained with kVp adjustments of only 2×s from the ideal do not warrant repeating.

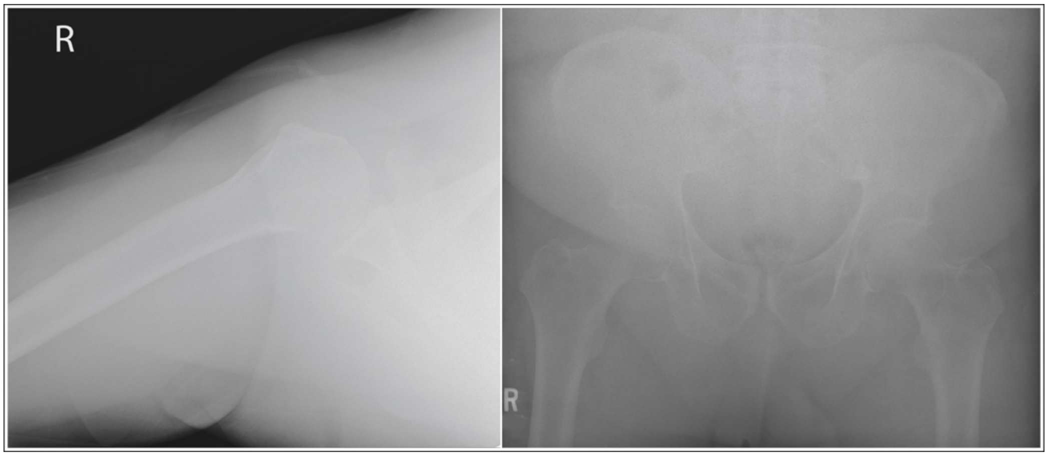


FIGURE 2.34 Both projections demonstrate quantum noise and EI numbers that indicate underexposure. The inferosuperior axial shoulder projection does not demonstrate the scatter fogging that is evident in the pelvis projection. This fogging and grayer appearance is due to greater patient thickness.

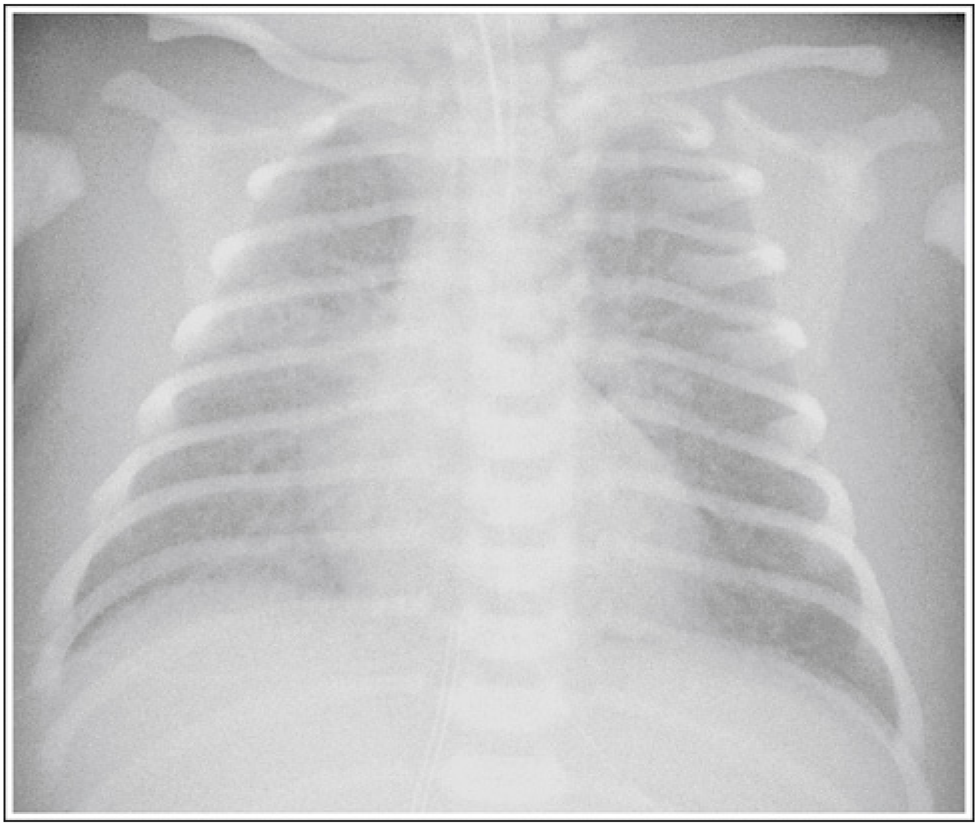


FIGURE 2.35 AP chest projection obtained with the CareStream CR and demonstrating quantum noise and an EI number of 1600. A 15% increase in kV will increase the EI the 300 points needed to bring it closer to the ideal EI number of 2000, improving contrast resolution and eliminating quantum noise.

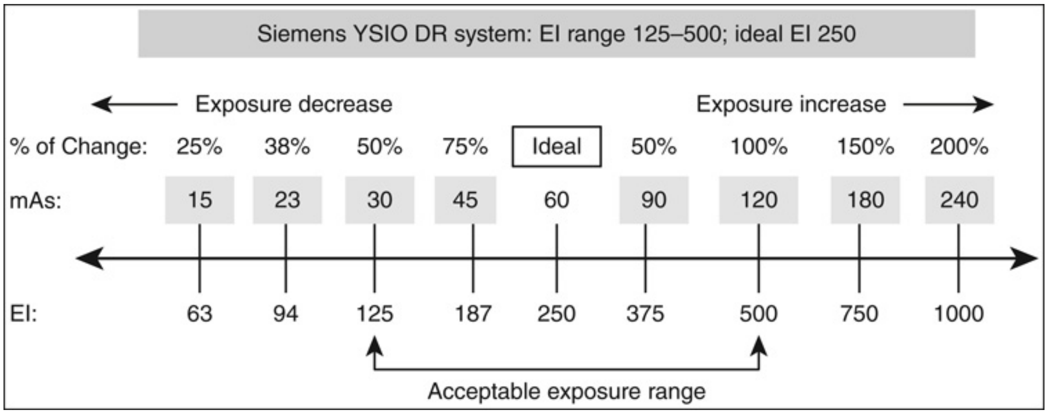


FIGURE 2.36 When the mAs is set too high or low to position the EI within the acceptable exposure range for the projection, it warrants repeating if quantum noise or saturation are demonstrated. The percentage of mAs change that is required when a poor projection is obtained should move the EI to the ideal exposure. As the figure shows, if quantum noise is demonstrated on a projection obtained by the Siemens YSIO DR system and the EI number is 63, a four times increase in mAs is required to move the EI to 250, or if saturation is present and the EI number is 1000, a four times decrease in mAs is required to move the EI to 250. Quantum mottle can be seen when the IR exposure is just below the acceptable range where saturation is partially seen with 4 to 5 times excessive IR exposure and full saturation occurs at 8 to 10 times in excessive IR exposure.

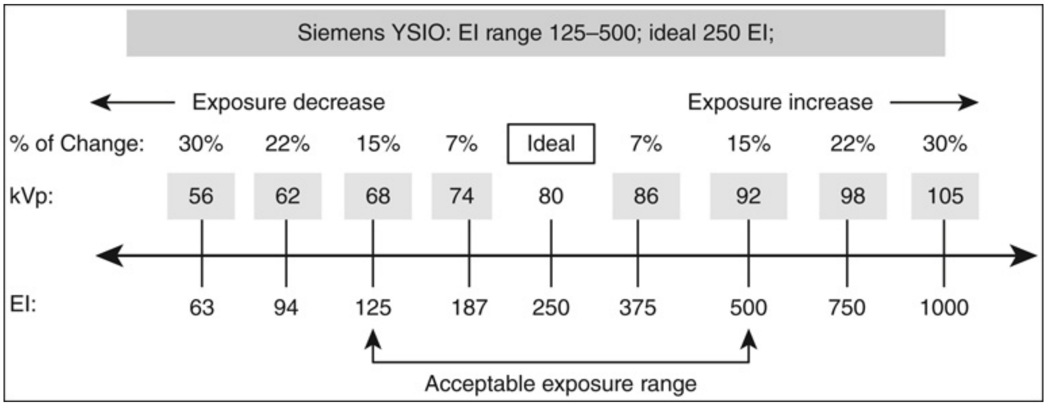


FIGURE 2.37 A 15% change in kVP is equivalent to a two times change in IR exposure using mAs. When making adjustments using kVp it is not advisable to make more than a 15% change from what is optimum for the body part being imaged unless something has significantly changed in the atomic density of that structure over what is considered routine. Extreme kVp adjustments may cause poor differential attenuation of the subject contrast.

FIGURE 2.38 The AP femur projection was obtained using the CareStream CR system. The projection has an EI of 2490, which indicates overexposure, but the structures in the VOI are all distinguishable even though they are gray because of scattered fogging. As long as contrast resolution is such that all aspects of the anatomic structure can be evaluated, it may not be necessary to repeat this

projection. Windowing can be used to adjust the brightness and contrast levels and reveal the hidden details. It should be noted though that when exposures are excessive, the reason for the overexposure requires researching to reduce exposure and radiation doses for the next similar examination.

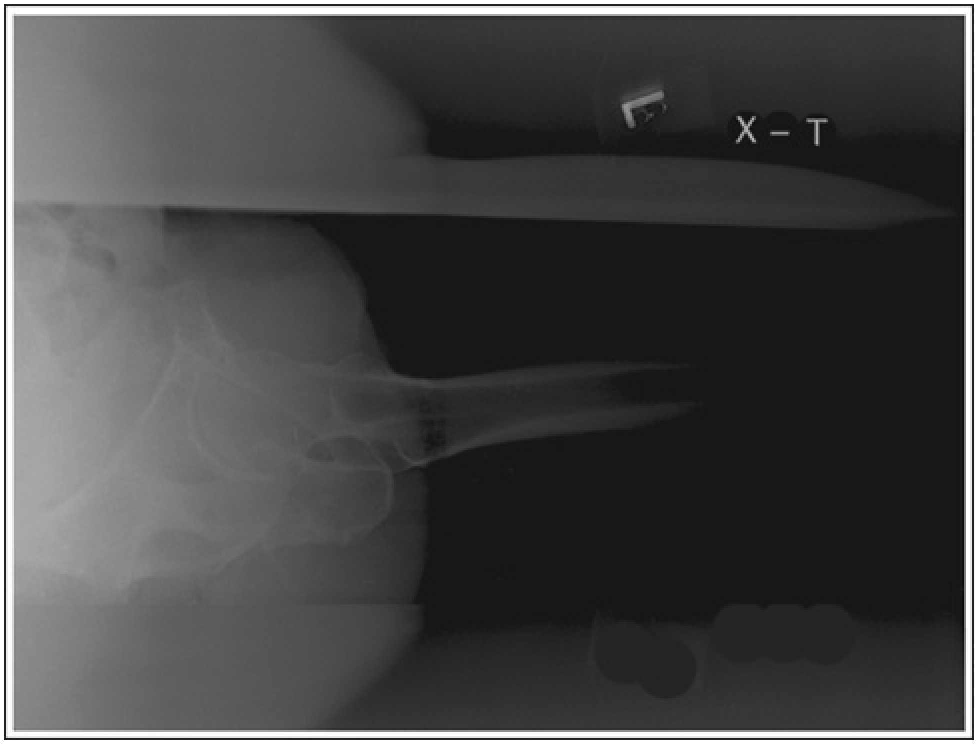


FIGURE 2.39 Proximal axiolateral femur projection demonstrating a loss of subject contrast and partial saturation due to overexposure.

TABLE 2.5

Underexposure

Identifying the Underexposed Projection

Underexposure that does not require the projection to be repeated but should be evaluated to determine how to improve IR exposure for future projections is identified when:

- No histogram analysis error is indicated.
- Brightness has been rescaled to the LUT.
- EI number is within the acceptable exposure range but is toward the underexposure indicator instead of at the ideal exposure parameter.
- Windowing improves detail visualization.

Underexposure that requires the projection to be repeated is identified when:

- No histogram analysis error is indicated.
- Brightness has been rescaled to the LUT.
- EI number is outside the acceptable exposure range toward underexposure (**Table 2.2**).
- VOI demonstrates a loss of subject contrast, with some or all of the details demonstrating a white shade (silhouette), and windowing does not make them visible (**Fig. 2.34**).
- SNR is low, with the presence of:
- Quantum noise in the thicker and denser anatomical details (most noticeable when postprocessing magnification is used; **Figs. 2.31**

Identifying the Underexposed Projection

and **2.35**)

- Scatter fogging across entire projection on thicker patients creating a gray appearance (see **Fig. 2.34**).

Steps for Determining Adjustment for Underexposure Using mAs and/or kVp

Step 1. Determine if a histogram analysis error has occurred (**Tables 2.1** and **2.3**). If no error is identified, proceed to step 2.

Step 2. Determine if the densest and thickest details in the VOI have been penetrated by looking to make certain that the bony cortical outlines are demonstrated. Cortical outlines that are not seen have not been penetrated.

- If there are cortical outlines that have not been penetrated, a kVp adjustment is required.
- If all of the cortical outlines have been penetrated, kVp can be adjusted up to 15% from optimal and the remainder made with mAs.

Step 3. Determine the total adjustment needed to move the EI number to the ideal value (**Table 2.2**) and eliminate quantum noise on the projection (**Figs. 2.36** and **2.37**).

- If projection demonstrates good penetration and the EI indicates insufficient IR exposure by a factor of 2, calculate a two times increase in IR exposure using mAs, *by multiplying the original mAs by 2 and adding the results to the original mAs. If the original mAs were 20, the new mAs would be 40.*

Identifying the Underexposed Projection

- If projection demonstrates poor penetration and the EI indicates insufficient IR exposure by a factor of 2 times, use the 15% rule that indicates for every 15% change in kVp the exposure to the IR is changed by a factor of 2. A 15% kVp change is calculated by multiplying the original kVp used by 0.15 and adding the results to the original kVp. If 60 kVp were used for the original projection, a 15% change would make the new kVp 69.
- If the EI indicates poor penetration and insufficient IR exposure by a factor of 4, as a general rule, no more than a 15% increase above optimum should be made with kVp in this situation because an increase too far above optimum may result in poor differential absorption and cause an increase in scatter radiation being directed toward the IR. The additional two times exposure adjustment is to be made with mAs.

Step 4. Scatter noise on thicker patients is reduced by decreasing the field size and by adding a grid or by using a grid with a higher grid ratio.

Other Causes of Underexposure and Adjustments

Grids

- Used a nongrid technique but left the grid in or used a low ratio grid technique with a high ratio grid: Use the grid conversion factor (GCF) in **Table 2.7** to determine the mAs adjustment needed.

Identifying the Underexposed Projection

- Grid off-level or CR is angled toward the grid's lead strips, demonstrating grid cutoff on the side that the CR is angled toward if parallel grid was used and across the entire projection if focused grid was used: level the grid, bringing it perpendicular to the CR. If angled CR is needed, change grid direction so CR is angled with the grid's lead strips.
- SID outside focusing range, demonstrating grid cutoff on each side of the projection: Increase or decrease the SID to bring distance in the grid's focusing range.
- Focused grid inverted, demonstrating grid cutoff on each side of the projection: Flip grid around.
- Focused grid off-center, demonstrating grid cutoff across entire projection; projection will not be in the center of the IR but will be to one side: center the CR to the center of the grid.

SID and OID (Make these adjustments prior to exposing the image to keep EI close to the ideal.)

- SID was increased without an equivalent increase in mAs: Use the density maintenance formula to adjust mAs for the SID change: old mAs/new mAs = old SID2/new SID2.
- Increased OID without an increase in mAs (only if procedure would produce a significant amount of scatter radiation that will not reach IR when OID is increased): Increase the mAs 10% for every 1 inch (2.5 cm) of OID increase.

Identifying the Underexposed Projection

Collimation (Make these adjustments prior to exposing the image to keep EI close to the ideal.)

- A large decrease in field size was made without an increase in mAs (only if procedure would produce a significant amount of scatter radiation that will not reach IR when OID is increased.): 14- × 17-inch field size to a 10- × 12-inch field size: Increase mAs by 35%; 14- × 17-inch field size to a 8- × 10-inch field size: increase mAs by 50%.

Additive patient condition (Make these adjustments prior to exposing the image to keep EI close to the ideal.)

- Patient had an additive condition that caused the tissues to have increased mass density or thickness, and require an increase in exposure: Adjust the mAs or kVp as indicated for the additive condition as listed in **Table 2.9**.

AEC

- Backup time was shorter than the needed exposure time: Set backup timer at 150%–200% of the expected manual exposure time.
- Density control was left on the minus (−) setting from the previous patient: Increase density control setting.
- Ionization chamber(s) was beneath a structure having a lower atomic number or was less dense or thinner than the VOI: Select

Identifying the Underexposed Projection

ionization chamber(s) centered beneath the VOI.

- Inadequate collimation caused excessive scatter radiation to reach the ionization chamber(s) and prematurely shut off exposure: Increase collimation.
- A small anatomic part was imaged and the activated ionization chamber was not fully covered by VOI or the AEC was used on a peripheral anatomic part and the activated ionization chamber was not fully covered by the VOI: Do not use the AEC. Manually set technique controls.

AEC, Automatic exposure control; *CR*, central ray; *EI*, exposure index; *IR*, image receptor; *kVp*, kilovoltage peak; *LUT*, lookup table; *mAs*, milliampere-seconds; *OID*, object–image receptor distance; *SID*, source–image receptor distance; *SNR*, signal to noise ratio; *VOI*, values of interest.

TABLE 2.6

Overexposure

Identifying the Overexposed Projection
Overexposure that does not require the projection to be repeated but should be evaluated to determine how to improve IR exposure for future projections is identified when: • No histogram analysis error is indicated. • Brightness has been rescaled to the LUT. • EI number is within the acceptable exposure range but is toward the overexposure indicator instead of at the ideal exposure parameter. • Windowing improves detail visualization (**Fig. 2.38**). Overexposure that requires the projection to be repeated is identified when: • No histogram analysis error is indicated. • Brightness has been rescaled to the LUT. • EI number is outside the acceptable exposure range toward overexposure (**Table 2.2**). • VOI demonstrates a loss of subject contrast, with some or all of the details demonstrating saturation, and windowing does not make them visible (**Fig. 2.39**). • SNR is low, with the presence of scatter fogging across entire projection on thicker patients creating a gray appearance.

Identifying the Overexposed Projection

Steps for Determining Adjustment for Overexposure Using mAs and/or kVp

Step 1. Determine if a histogram analysis error has occurred (**Tables 2.1** and **2.3**). If no error is identified, proceed to step 2.

Step 2. Determine if the least dense and thinnest details in the VOI have been saturated by windowing the projection. If details are not made visible, saturation has occurred and the projection requires repeating. *A portion of the VOI is saturated if the IR exposure is four or five times the ideal and the VOI is total saturation when eight to ten times of the ideal IR exposure is reached*.

Step 3. Determine how much the kVp and/or mAs needs to be adjusted to move the EI number to the ideal value (**Table 2.2**) and eliminate saturation on the projection (**Figs. 2.36** and **2.37**).

- If the projection differentiates the subject contrast with an intermediate contrast, the kVp was within 15% of optimum, and the EI indicates excessive IR exposure by a factor of 4, calculate a four times decrease in IR exposure using mAs *by dividing the original mAs by 4. If the original mAs were 20, the new mAs would be 5.*
- If the subject contrast is not clearly differentiated because of low contrast, the kVp was set at more than 15% above optimum or the VOI demonstrates an additive disease process (**Table 2.9**), and the EI number indicates excessive IR exposure by a factor of 4, *use the 15% rule that indicates for every 15% change in kVp the exposure to the IR is changed*

Identifying the Overexposed Projection

by a factor of 2. A 15% decrease in kVp is calculated by multiplying the original kVp used by 0.15 and subtracting the results from the original kVp. If 90 kVp were used for the original projection, a 15% change would make the new kVp 77. The additional two times exposure adjustment is to be made with mAs. It should be noted that above 80 kVp absorption no longer occurs in soft tissue and above 120 kVp absorption no longer happens in bone.

Step 4. Scatter noise on thicker patients is reduced by decreasing the field size and by adding a grid or by using a grid with a higher grid ratio.

Other Causes of Overexposure and Adjustments

Grids

- Used a grid technique without a grid or used a high ratio grid technique with a low ratio grid: Use the grid conversion factor (GCF) in **Table 2.7** to determine the mAs adjustment needed.

SID (Make these adjustments prior to making the exposure to keep EI close to the ideal.)

- SID was decreased without an equivalent decrease in mAs: Use the density maintenance formula to adjust mAs for the SID change: *old mAs/new mAs = old SID* ^{2} */new SID* ^{2} .

Identifying the Overexposed Projection

Destructive patient condition (Make these adjustments prior to making the exposure to keep EI close to the ideal.)

- Patient had a destructive condition that caused the tissues to have decreased mass density or thickness, and require a decrease in exposure: Adjust the kVp as indicated for the destructive condition as listed in **Table 2.9**.

AEC

- Wrong IR was activated and the backup timer was set at too long of an exposure time: Activate correct IR.
- Exposure time needed was less than the minimum response time: Reduce mA station until time needed for exposure is above minimum response time.
- Density control was left on the plus (+) setting from the previous patient: Decrease density control setting.
- Ionization chamber(s) was beneath a structure having a higher atomic number or was denser or thicker than the VOI: Select ionization chamber(s) centered beneath the VOI.
- A radiopaque artifact or appliance is included within or over the VOI: Do not use AEC. Manually set technique controls.

AEC, Automatic exposure control; *EI*, exposure index; *IR*, image receptor; *kVp*, kilovoltage peak; *LUT*, lookup table; *mAs*, milliampere-seconds; *VOI*, values of interest.

Grids

When a grid is added or the technologist changes from one grid ratio to another, IR exposure will be inadequate and a repeat will be necessary unless the mAs is adjusted to compensate for the resulting change in scatter radiation cleanup and primary radiation absorption that takes place in the grid (**Table 2.7**). When changing to a higher grid ratio, an increase in mAs is needed or insufficient IR exposure will result; when changing to a lower grid ratio, a decrease in mAs is needed or excessive IR exposure to the IR and patient will result.

Insufficient IR exposure will result when the grid and CR are misaligned, causing a decrease in the number of remnant photons from reaching the IR and grid cutoff. The exposure decrease caused by grid cutoff can be distinguished from other underexposure problems by the additional appearance of grid lines (small white lines) on the projection where the cutoff is demonstrated.

Source–Image Receptor Distance

Increasing the source–image receptor distance (SID) will decrease IR exposure and decreasing the SID will increase IR exposure by the inverse square law, because the area through which the x-rays are distributed is spread out or condensed, respectively, with distance changes. *To keep the EI number at the ideal, any change in SID of greater than 10% should be compensated for by adjusting the mAs by the exposure maintenance formula ([new mAs]/[old mAs] = [new distance* ^{2} *]/[old distance* ^{2} *]).*

Object–Image Receptor Distance

Although it is standard to maintain the lowest possible object–image receptor distance (OID), there are situations in which increasing the OID is

unavoidable, such as when the patient is in traction and the device extends beyond the anatomic structure being imaged. Increasing the OID may result in a noticeable decrease in IR exposure because of the reduction in the amount of scatter radiation detected by the IR when a portion of the scattered x-rays generated in the patient are scattered at an angle that is away from the IR. The amount of exposure loss will depend on the degree of OID increase and the amount of scatter that would typically reach the IR for such a procedure, which is determined by the field size, patient thickness, and kVp selected. A larger field size and body part thickness affects the amount of scatter produced, with more production resulting in increased reduction of scatter reaching the IR as the OID increases. As tube potentials are raised above 60 kV, scatter radiation is directed in an increasingly forward direction, so the IR will experience exposure loss as the OID is increased and scatter misses the IR. *When an OID increase causes significant scatter radiation to be diverted from the IR, the mAs should be increased by about 10% for every 1 inch (2.5 cm) of OID to compensate and to keep the EI number at the ideal.*

FIGURE 2.40 AP femur projection demonstrating grid lines across the entire image because the focused grid was off level.

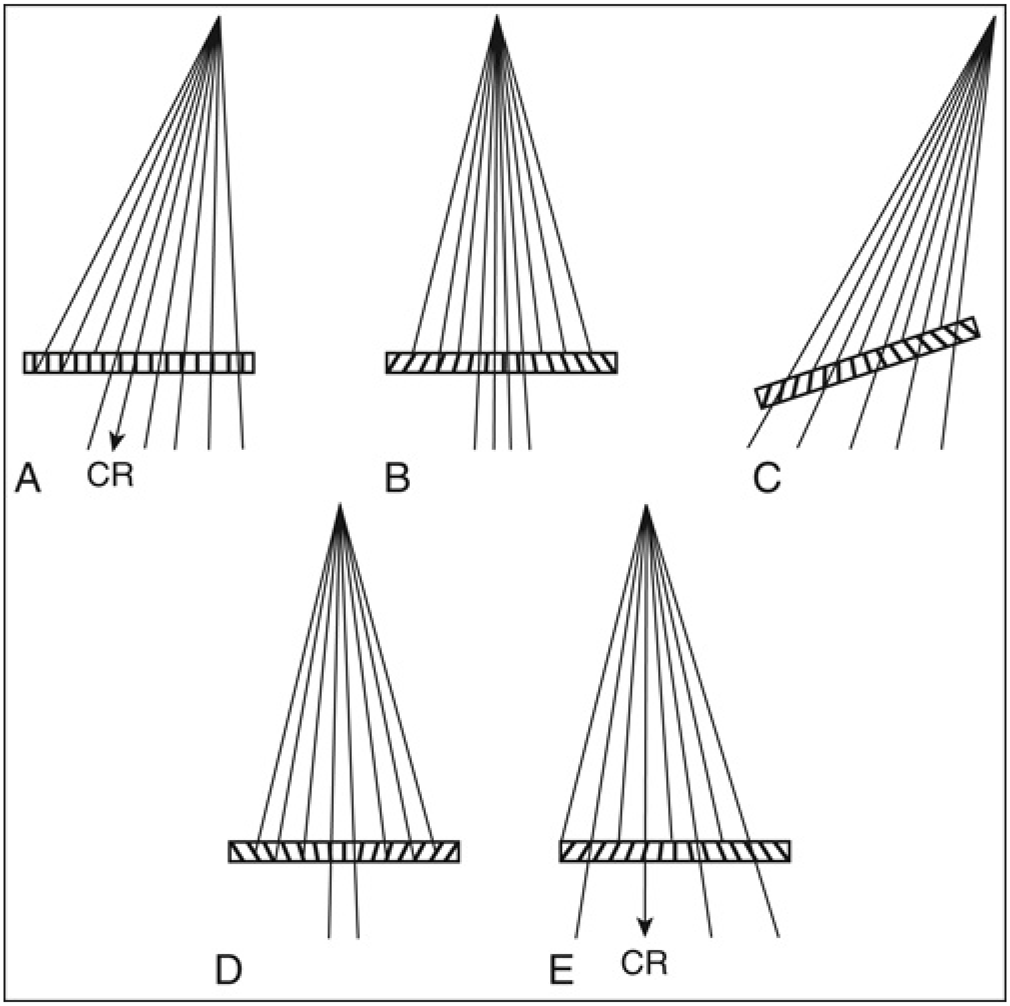


FIGURE 2.41 Causes of grid cutoff. (A) CR angled against grid's lead lines. (B) Off focus. (C) Off level. (D) Inverted. (E) Off center.

TABLE 2.7

CR, Central ray; *GCF*, grid conversion factor; *mAs*, milliampere-seconds; *SID*, source–image receptor distance.

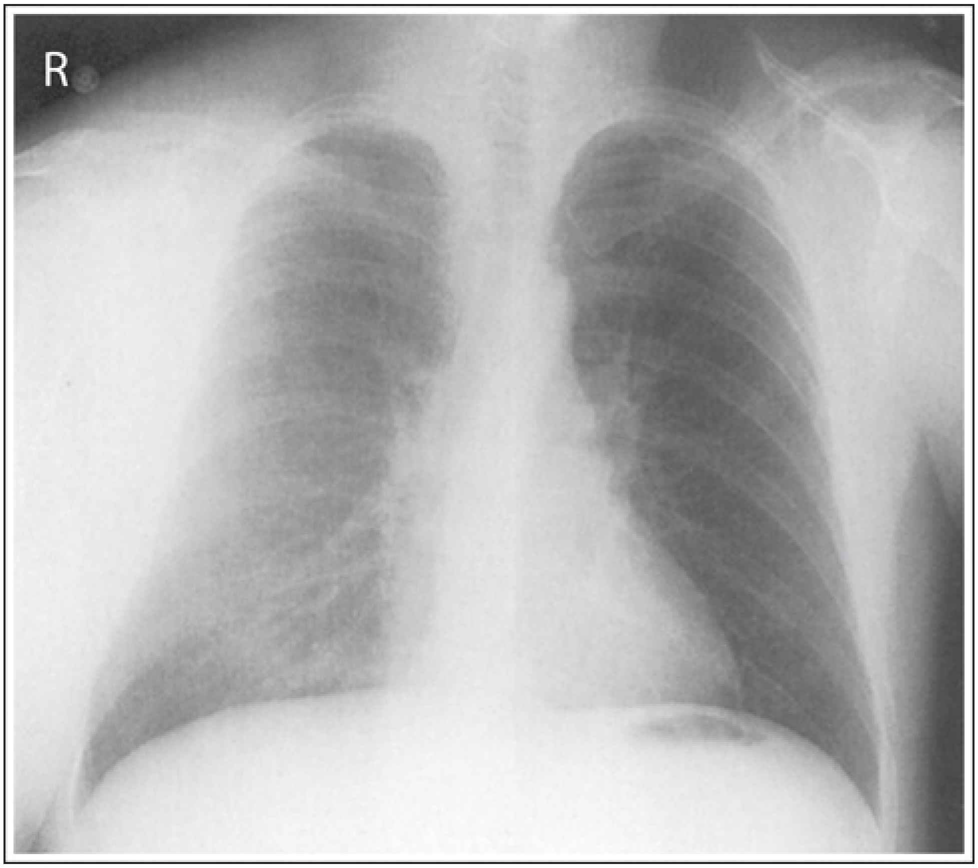


FIGURE 2.42 AP chest projection demonstrating right side grid cutoff because the parallel grid was tilted or CR angled toward the right side.

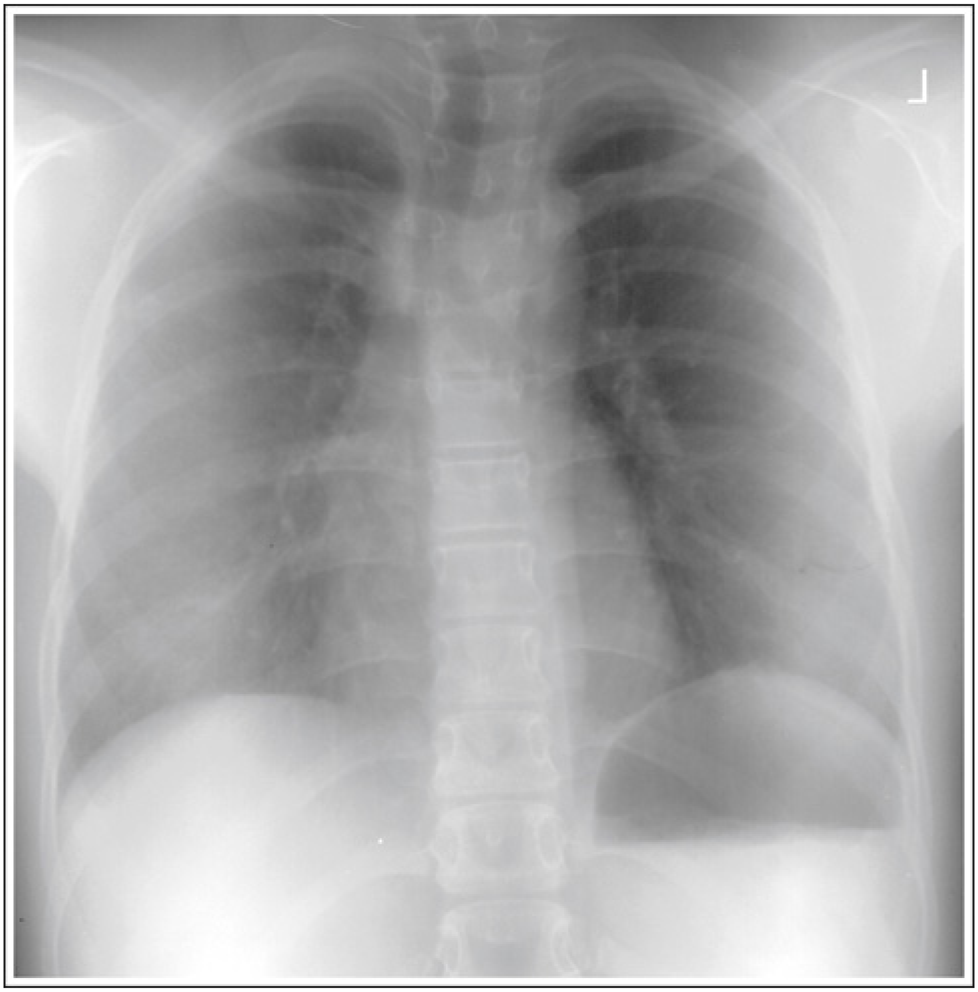


FIGURE 2.43 PA chest projection demonstrating peripheral grid cutoff because the SID was outside the grid's focus range.

Collimation

A decrease in the area exposed on the patient, as determined by collimation, changes the amount of scatter radiation produced and hence the amount of scatter reaching the IR and the overall IR exposure. The amount of exposure change will depend on the field size and the amount of scatter that would typically reach the IR for such a procedure, which is determined by the patient thickness and the kVp selected. The mAs needs to be increased

to compensate for the exposure that is lost when the field size is significantly reduced on a procedure that produces significant scatter radiation. This mAs adjustment will keep the EI number at the ideal. A 35% mAs adjustment is needed for a field size change from a 14- × 17-inch to a 10- × 12-inch, and a 50% mAs change is needed for a field size change from a 14- × 17-inch to an 8- × 10-inch.

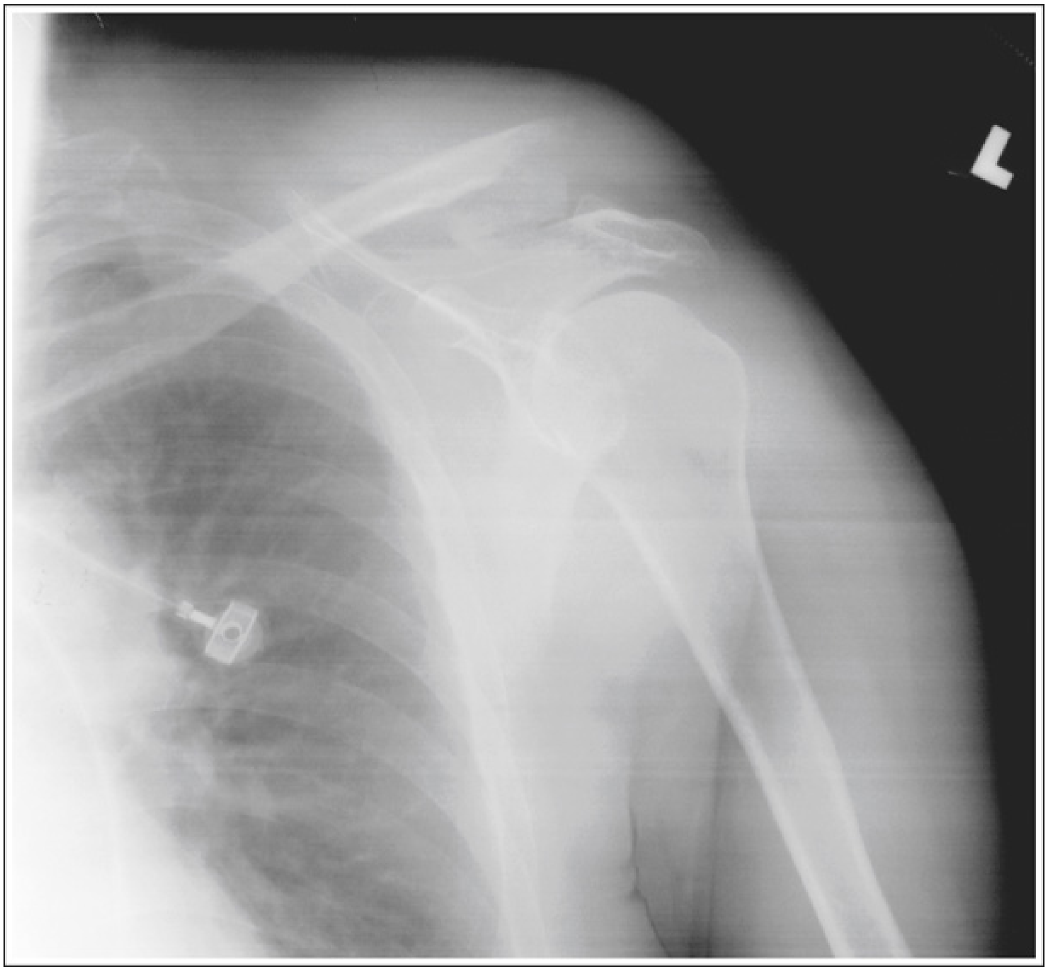


FIGURE 2.44 PA oblique shoulder projection demonstrating grid cutoff across the entire image because the focus grid was not level or the CR was angled toward the grid's lead strips.

FIGURE 2.45 AP oblique shoulder projection demonstrating grid cutoff peripherally because the grid was positioned upside down.

FIGURE 2.46 AP pelvis projection demonstrating grid cutoff across the entire image because the CR was not centered to the grid.

FIGURE 2.47 Equipment-related artifact—Moiré grid artifact. Courtesy Cesar LJ, Schueler BA, Zink FE, et al. Artefacts found in computed radiography. Br J Radiol. 001;74:195–202.

Anode Heel Effect

The anode heel effect is considered when a 17-inch (43-cm) or longer field length is used to accommodate the structure, as with long bones and the vertebral column. When this field length is used, a noticeable intensity variation occurs across the entire field size that is significant enough between the ends of the field that when they are compared, it can be seen. This intensity variation is a result of the greater photon absorption that occurs at the thicker “heel” portion of the anode compared with the thinner “toe” portion when a long field is used. Consequently, intensity at the anode end of the tube is lower because fewer photons emerge from that end of the tube than at the cathode end. This knowledge can be used to help produce images of long bones and vertebral columns that demonstrate uniform brightness at both ends. **Table 2.8** provides guidelines for positioning structures to take advantage of the anode heel effect. Although this factor will not require a kV or mAs adjustment if done incorrectly, it may demonstrate signs of underexposure or overexposure of the structure at most proximal and distal aspects.

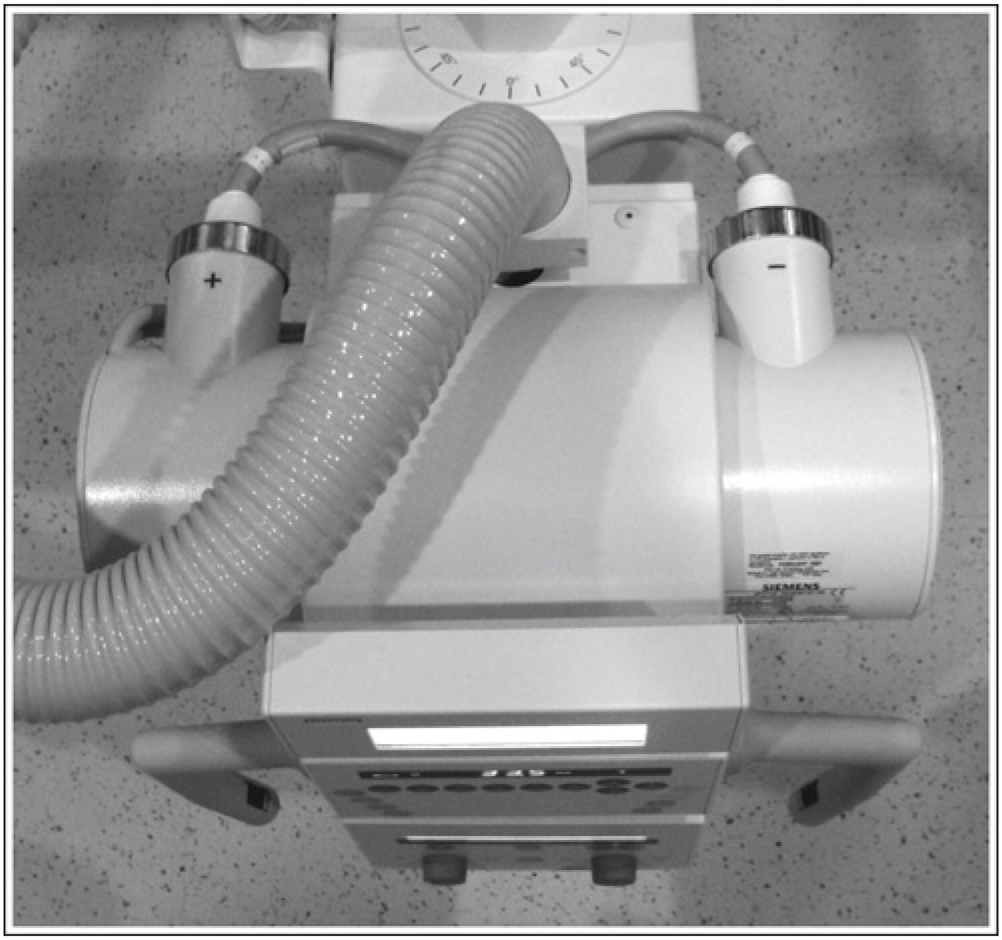


FIGURE 2.48 Imaging rooms are generally designed so that when the patient is placed on the imaging table the head end is positioned on the technologist's left side (when facing the imaging table), placing the anode end of the x-ray tube at the head end of the patient. The placement of the anode end of the tube may vary in reference to the patient as the tube is moved into the horizontal position. To identify the anode and cathode ends of the x-ray tube, locate the + and − symbols attached to the tube housing where the electrical supply enters. The + symbol is used to

identify the anode end of the tube and the − symbol indicates the cathode end.

FIGURE 2.49 The AP lower leg projection was obtained using the anode heel effect, providing uniform brightness across the part. The AP forearm was obtained with the wrist positioned at the cathode

end of the tube, where more exposure caused it to be darker than the elbow.

TABLE 2.8

CR, Central ray; *IR*, image receptor; *mAs*, milliampere-seconds.

Additive and Destructive Patient Conditions

Additive and destructive patient conditions that result in change to the normal bony structures, soft tissues, or air or fluid content of the patient require technical adjustments to compensate for the exposure change that the condition causes over the routine used. Additive diseases cause tissues to increase in mass density or thickness, resulting in them being more radiopaque, whereas destructive diseases cause tissues to break down, resulting in them being more radiolucent. **Table 2.9** lists common additive and destructive diseases that require technique adjustments and provides a starting point for adjusting technical factors for the condition.

Automatic Exposure Control

The automatic exposure control (AEC) allows the mAs to be automatically determined by controlling the exposure time, but it is the technologist's responsibility to set an optimum kV and mA manually. Optimum mA refers to using a high enough mA at a given focal spot size to minimize motion, but not so high that the exposure times are shorter than the AEC minimum response time. The minimum response time is the time that it takes for the circuit to detect and react to the radiation received; this is determined by the AEC manufacturer settings. The factors in **Table 2.10** are best practice guidelines to consider when setting the AEC for optimal IR exposure.

TABLE 2.9

kVp, Kilovoltage peak; *mAs*, milliampere-seconds.From Carroll QB. *Practical Radiographic Imaging*. 8th ed. Springfield, IL: Charles C. Thomas; 2007.

Postprocessing

Windowing

DR allows for postprocessing manipulation of the image's brightness and contrast to demonstrate the VOI more accurately. This process, called *windowing*, occurs after the image is displayed on the monitor. Adjusting the window level allows the viewer to change the average gray level (center gray shade on the dynamic range) for the projection toward lighter or darker shades, increasing or decreasing the overall brightness. Adjusting the window width changes the length of the dynamic range used for the projection by adding or subtracting gray shades, which increases or decreases the difference between adjacent shades and contrast resolution. When contrast is changed by adjusting the window width, there is often a perceived difference in image brightness, with decreased width (shorter gray scale) appearing brighter and increased width appearing less bright. This is a result of additional structures being given lighter and darker gray values, respectively. As long as the window level does not change, the average brightness level remains unchanged.

To provide the latitude for image brightness to be adjusted for underexposures and overexposures by a factor of 2 and the long gray scale to adjust contrast resolution, the original image data needs to be maintained. Technologists are to avoid adjusting the window width and level to improve image quality and then saving the new window settings to the picture

archival and communication system (PACS). Once windowing has been done and the image saved to PACS, the total data from the original image histogram cannot be restored from PACS, leaving only the range that was saved. The radiologist is then left with a narrower dynamic range of settings to use when evaluating different aspects of the image. A better practice is to return to the original data set after windowing has proven to display the needed details and it's confirmed a repeat is not needed before saving to PACS.

Artifacts

An artifact is any undesirable structure or substance recorded on an image. Before a projection is taken, it may be wise to have the patient change into a hospital gown and to ask whether any patient belongings are in or around the area being imaged. Patients are often nervous and may forget to remove articles of clothing, or for sentimental reasons they may not remove jewelry, so you should recheck the VOI, even after the patient has changed into a gown. Once the patient is positioned and the IR is ready to be exposed, take a last look to make sure that all hospital possessions that can be moved out of the imaging field have been moved. Check that those items that must remain in the field, such as heart monitoring leads, have been shifted so that they will superimpose the least amount of information. It would be impossible to delineate in this book all the possible artifacts that can appear on an image, but it is important for technologists to familiarize themselves with as many artifacts as possible.

TABLE 2.10

Best Practice Guidelines for Automatic Exposure Control Use

- Set optimum kVp for the body part being imaged to best demonstrate the subject contrast.
- Set mA at the highest station for the focal spot size needed so low exposure times are used, but not so high that the exposure time that would be needed for proper IR exposure is less than the minimum response time.
- Set backup time at 150%–200% of the expected manual exposure time. As a general guideline:
- Use 0.2 s for all chest and proximal extremity projections.
- Use 1 s for abdominal and skull projections.
- Use 2–4 s for very large torso projections.
- Backup timer is the maximum time that the x-ray exposure is allowed to continue. Once the backup time is met the exposure automatically terminates.
- If the set backup time is too short, the exposure stops before adequate IR exposure has reached the ionization chamber(s), resulting in underexposure.
- If the set backup time is too long, because the AEC is not functioning properly or the control panel is not correctly set, the exposure continues much longer than needed, resulting in overexposure.
- Select and activate the ionization chamber(s) that is centered beneath the VOI. Recommendations for ionization chamber

selection are located at the beginning of each procedural analysis chapter of the text.

- Failure to properly activate the correct ionization chamber(s) and center the VOI beneath it results in projections that are over- or underexposed.
- An overexposed projection results when the chamber chosen is located beneath a structure that has a higher atomic number or is thicker or denser than the VOI (**Fig. 2.50**).
- An underexposed projection results when the chamber chosen is located beneath a structure that has a lower atomic number or is thinner or less dense than the VOI (**Fig. 2.51**).
  - Do not use AEC on structure that will not cover the activated chamber(s) (**Fig. 2.52**).
  - Tightly collimate to the VOI to reduce scatter radiation from the imaging table or body that may cause the AEC to shut off prematurely.
  - Do not use the AEC when the VOI is in close proximity to thicker structures and both will be situated above the activated ionization chamber (**Fig. 2.53**).
  - Never use the AEC when any type of radiopaque hardware or prosthetic device will be positioned above the activated chamber(s). For these situations, use a manual technique (**Fig. 2.54**).
  - Make certain that no external radiopaque artifacts such as lead sheets or sandbags are positioned over the activated chamber(s).
  - Exposure (density) controls can temporarily be used when AEC equipment is out of calibration and to fine tune IR exposure when the VOI and activated chamber(s) are only slightly misaligned.

- The exposure (density) controls change the preset exposure halt signals, increasing or decreasing the amount of IR exposure needed before the signal is sent to terminate the exposure, adjusting IR exposure by the control setting amount.
- Typical exposure control settings change the exposure level by increments of 25%, with the +1 and +2 buttons increasing the exposure and the −1 and −2 buttons decreasing the exposure. The 1 buttons will result in a 25% exposure change and the 2 buttons in a 50% exposure change. Some facilities have the AEC exposure controls set to obtain a 100% exposure increase and a 50% exposure decrease.

Correcting Exposure When Using AEC

When a projection that was obtained using the AEC demonstrates under- or overexposure:

- Fix VOI centering errors if applicable.
- Switch to manual technique and use the mAs readout and EI number displayed on the projection to adjust the technical factors as indicated in **Tables 2.5** and **2.6**.

AEC, Automatic exposure control; *IR*, image receptor; *kVp*, kilovoltage peak; *LUT*, lookup table; *mA*, milliampere; *VOI*, values of interest.

Most possession-related artifacts are demonstrated on the image at brightness levels that are lighter gray than the anatomic structures that surround them. **Table 2.11** lists the different categories of image artifacts

and common examples of each. If an artifact that can be eliminated obscures any portion of the VOI, the projection needs to be repeated. A gown snap superimposed on an area of the lungs on a chest projection can easily obscure a small lesion. A ring can easily obscure a hairline finger fracture. If the artifact is located outside the field of interest, the image does not need to be repeated.

Postprocedure Requirements

Defining Image Acceptability

When a projection meets all the necessary requirements, it is considered optimal and is ready to be sent to PACS. When a projection is not optimal but may be acceptable, the question arises as to whether it is poor enough to repeat or whether the information needed can be obtained without exposing the patient to further radiation. Factors that should be considered when making this decision include the following:

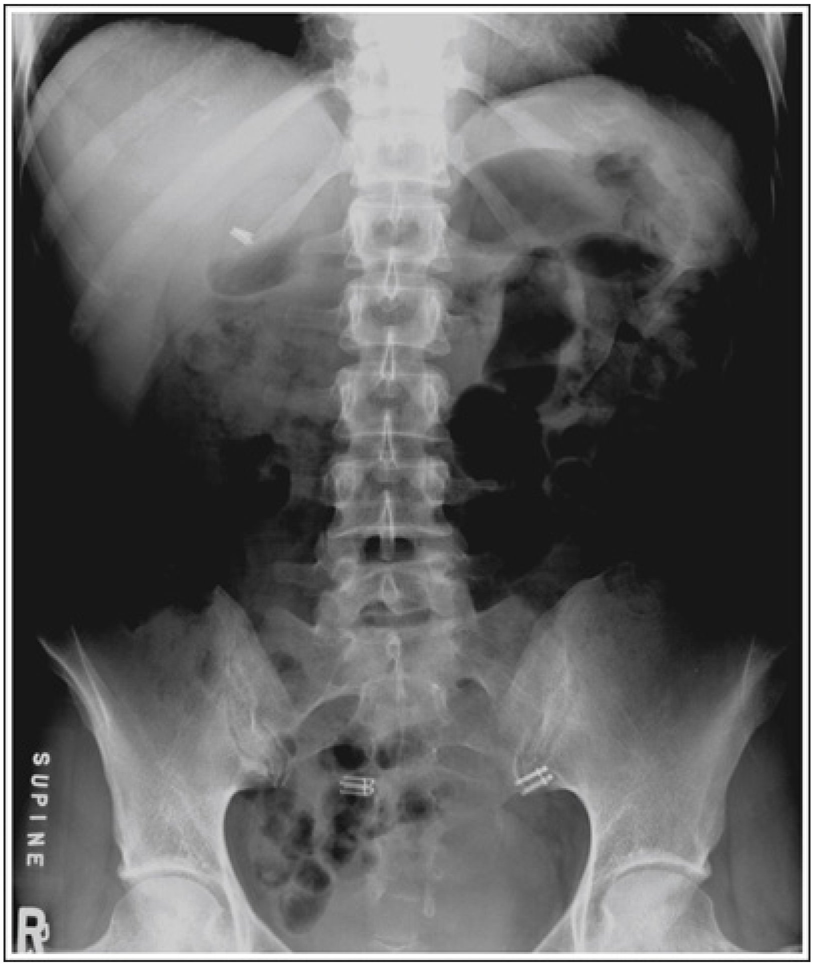


FIGURE 2.50 AP abdomen projection that was taken with the center ionization chamber chosen instead of the outside chambers. If the chamber situated under the lumbar vertebrae is used, the capacitor requires a longer exposure time to reach its maximum filling level and terminate the exposure. This occurs because of the high atomic number of bone and the higher number of photons that bone absorbs compared with soft tissue. The result will be a projection that demonstrates overexposure and the potential of saturation in the soft tissue areas.

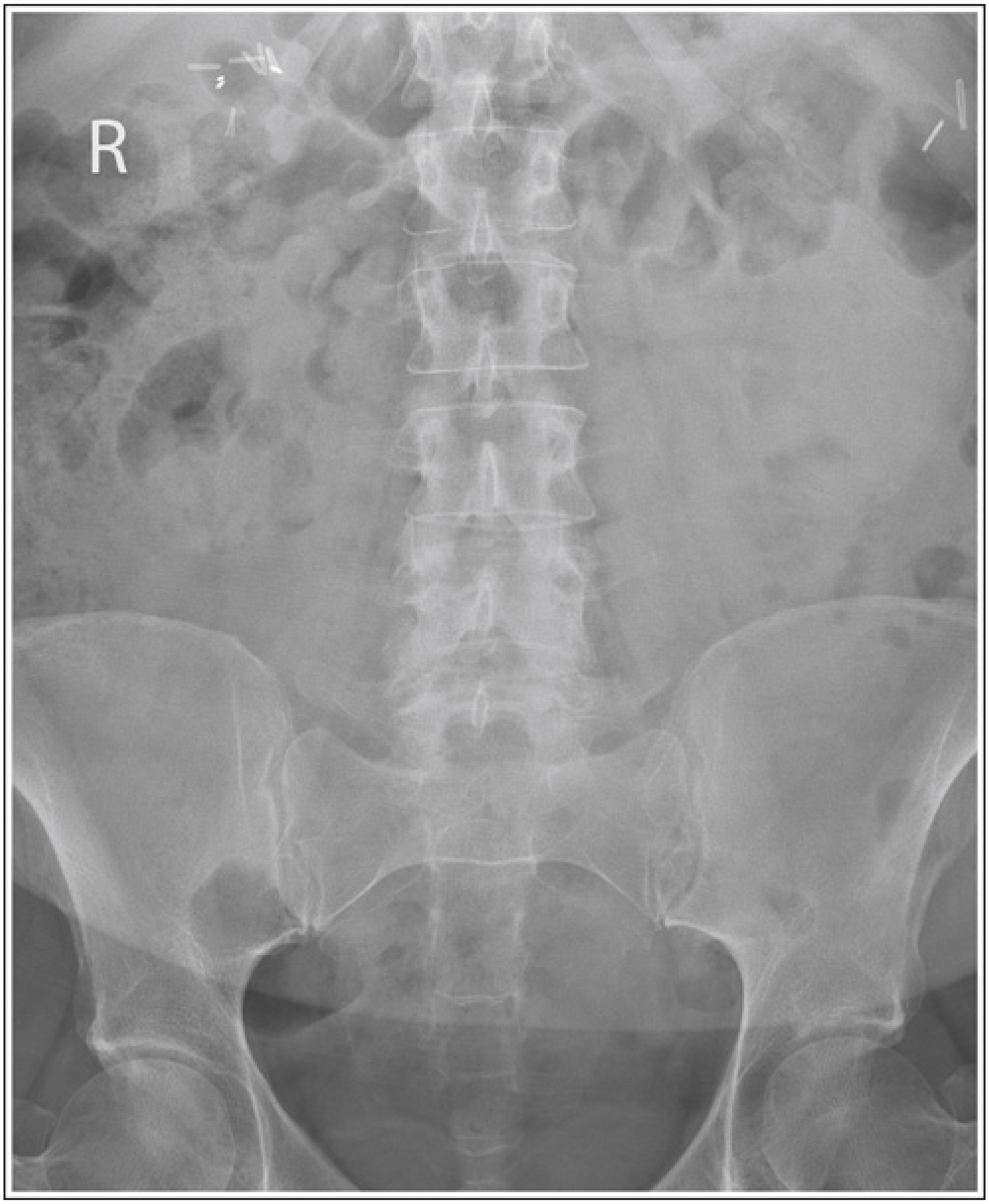


FIGURE 2.51 AP lumbar spine projection obtained using the outside AEC chambers.

FIGURE 2.52 AP oblique shoulder projection that was exposed with the center AEC chamber positioned too laterally.

FIGURE 2.53 AP atlas and axis (open-mouthed) projection obtained using the center AEC chamber.

- Your facility's standards
- The age and condition of the patient
- The conditions under which the patient was imaged
- Whether obvious pathology is evident
- Whether the indications for the examination have been fulfilled
- Whether windowing or modifying the projection by processing it with a different procedural algorithm will display the needed information

Each facility has its own standards that will determine whether a projection needs to be repeated. If standards are low, improving imaging

skills can raise them, thereby increasing the accuracy of diagnosis. The age and condition of the patient, as well as the conditions under which the patient was imaged, are most important in the decision to repeat a projection. Sometimes a less than optimal projection must be accepted because repeating the projection is impossible, as in a surgery case; at other times, the patient cannot or will not cooperate. Whenever a projection is accepted that does not meet optimal standards, record in the patient's history any information about the patient's condition or situation that resulted in acceptance of this projection. A less than optimal projection may also be accepted when the indication for the examination is clearly fulfilled by the projections obtained. It is important that all unacceptable projections and those less than optimal projections that have been accepted are studied to determine whether the situation(s) that caused them could be eliminated on future examinations. When a projection is repeated, the overall radiation dose to the patient increases and the cost of patient care rises because reimaging requires more technologist time, supplies, and equipment use.

FIGURE 2.54 Radiopaque materials, such as metal, lead sheets, or sandbags, have a much higher atomic number than that of the bony and soft tissue structures of the body. When a radiopaque material is situated within the activated chamber(s), the AEC will attempt to expose the radiopaque structure adequately,

resulting in the anatomic structures being overexposed and demonstrating poor contrast resolution and possible saturation.

Special Imaging Situations

Mobile and Trauma Imaging

The goal of mobile and trauma imaging is to produce optimal images without causing further patient injury and with minimal patient discomfort. The following are general guidelines for obtaining this goal.

1. Based on the requested order, determine the projections that will be needed and the order in which they will be completed. First, obtain the projections that will provide information about the most life-threatening condition (cross-table lateral cervical vertebrae projection if a cervical fracture is questioned or when obtaining an AP chest projection for a patient having difficulty breathing). Speed is of the essence in many mobile and trauma situations, because the patient can be quite ill. Having a thought-out plan of action before starting allows the technologist to work in an organized and speedy manner. As a general rule, after the initial projections associated with life-threatening conditions have been exposed and checked by the radiologist or physician, the remaining projections are exposed in an order that will require the least amount of CR adjustment. All AP projections are exposed, and then the CR is moved horizontally for the lateral projections. It is important that projections be obtained that are at 90-degree angles from each other (AP-posteroanterior [PA] and lateral) when fractures and foreign bodies

are suspected to determine the degree of bone displacement (**Fig. 2.66**) and depth location.

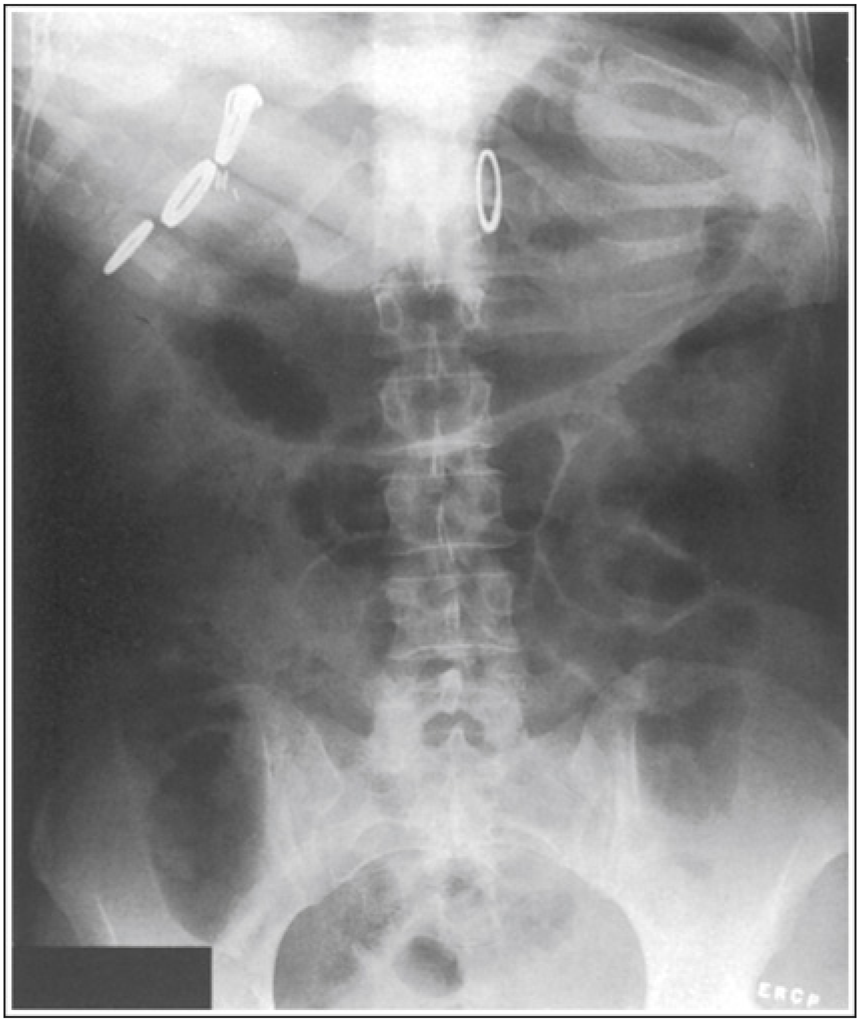


FIGURE 2.55 AP abdomen projection obtained in the supine position in which the patient's hands are superimposed over the upper abdominal region. More than likely, the patient was not positioned in this manner when the technologist left the room. After the technologist positioned the patient and before the exposure was taken, however, the patient found a more comfortable position. This example stresses the importance of explaining examinations to patients so that they understand how important it is for them to remain

in the position in which the technologist placed them. This also shows the importance of rechecking each patient's position before the exposure is taken if much time has elapsed between positioning the patient and exposing the projection. It is also not uncommon for a patient who is experiencing hip or lower back pain from lying on the imaging table to place a hand beneath the affected hip, resulting in superimposition of the hip and hand on the projection.

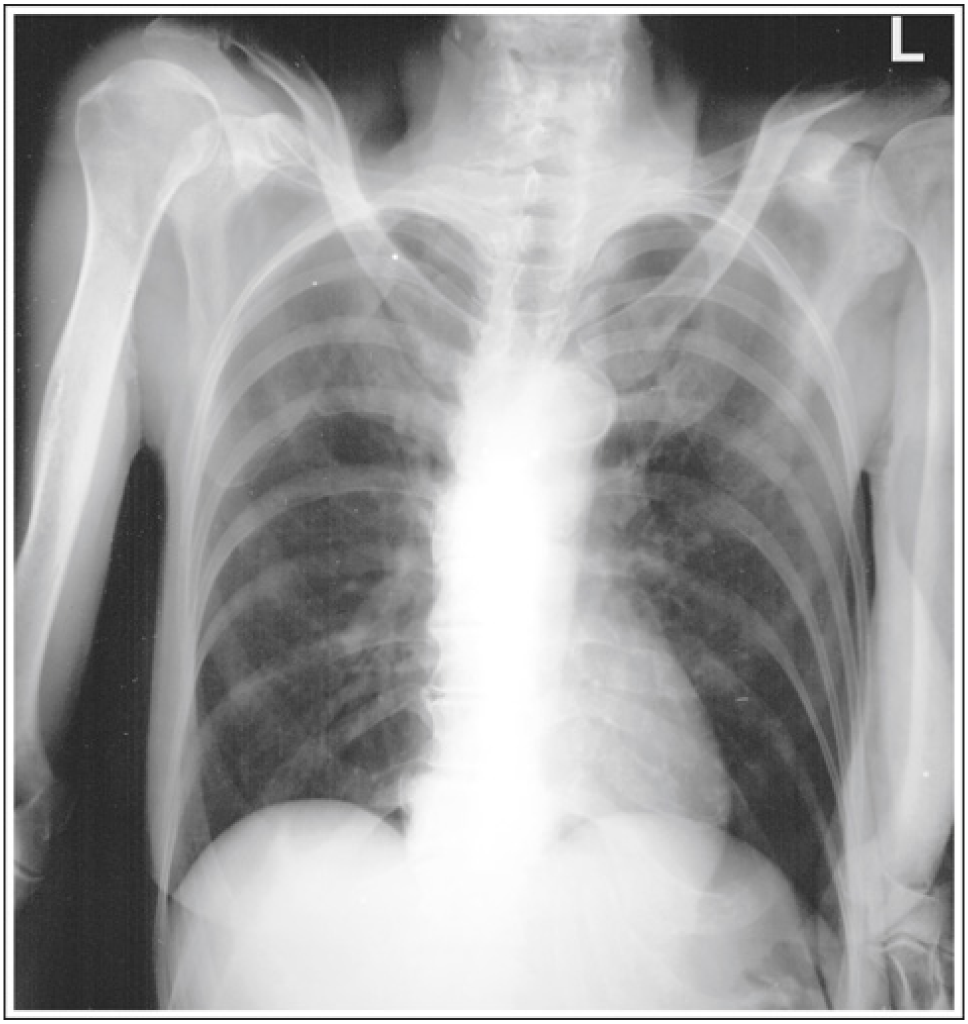


FIGURE 2.56 AP chest projection produced with a mobile x-ray machine and was taken with the arms positioned tightly against the sides. Because the humeri are not evaluated on a chest projection, there is no reason for them to be included, and they could be positioned outside the exposure field.

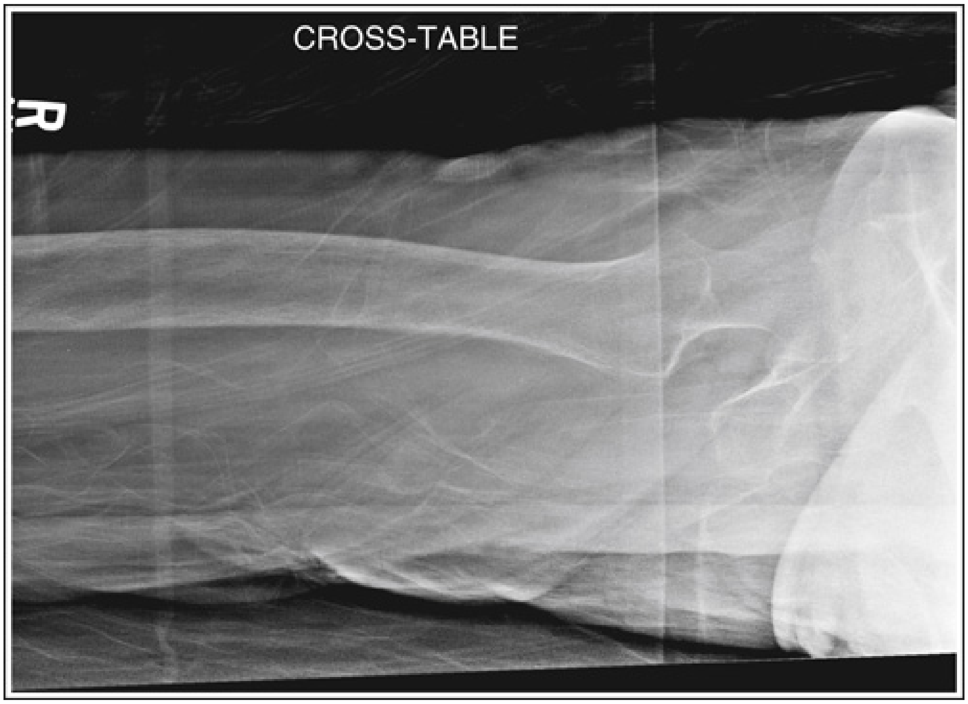


FIGURE 2.57 Lateral femur projection with clothing artifacts. Most external artifacts can be avoided with proper patient preparation.

FIGURE 2.58 AP abdomen projection showing an external artifact from a pillow.

TABLE 2.11

EI, Exposure index; *IP*, imaging plate; *IR*, image receptor; *VOI*, values of interest.

FIGURE 2.59 Lateral knee projection showing external and internal artifacts caused by imprint of patient clothing and leg prosthesis.

FIGURE 2.60 AP hip projection showing an internal artifact caused by a prosthesis.

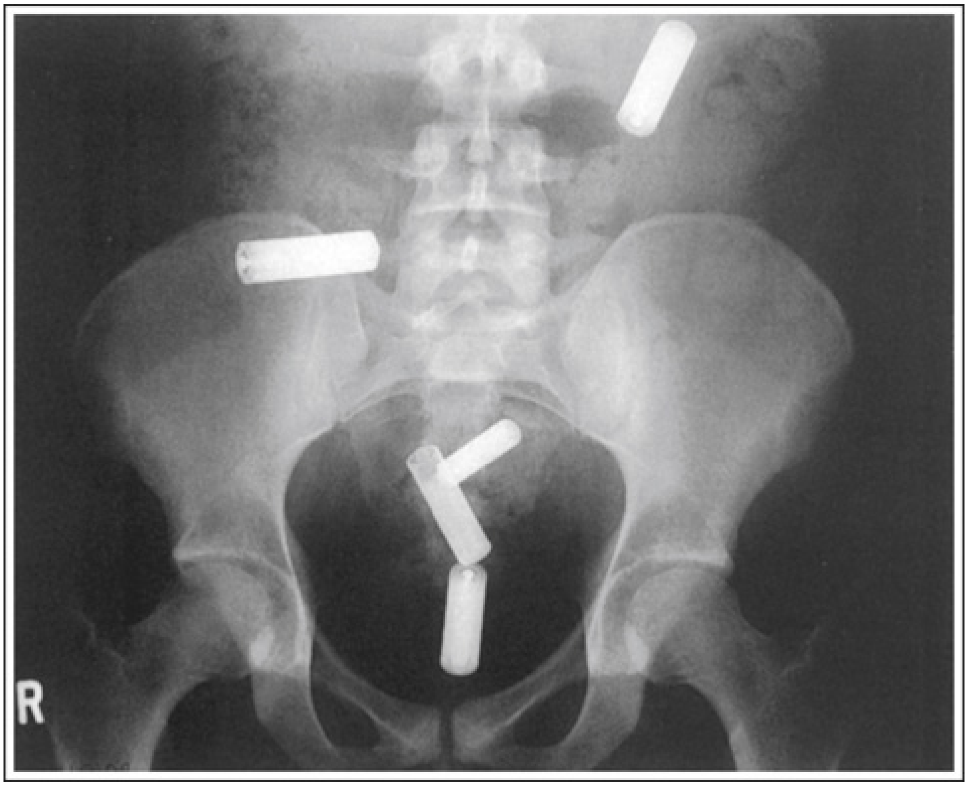


FIGURE 2.61 AP pelvis projection showing an internal artifact (five swallowed batteries).

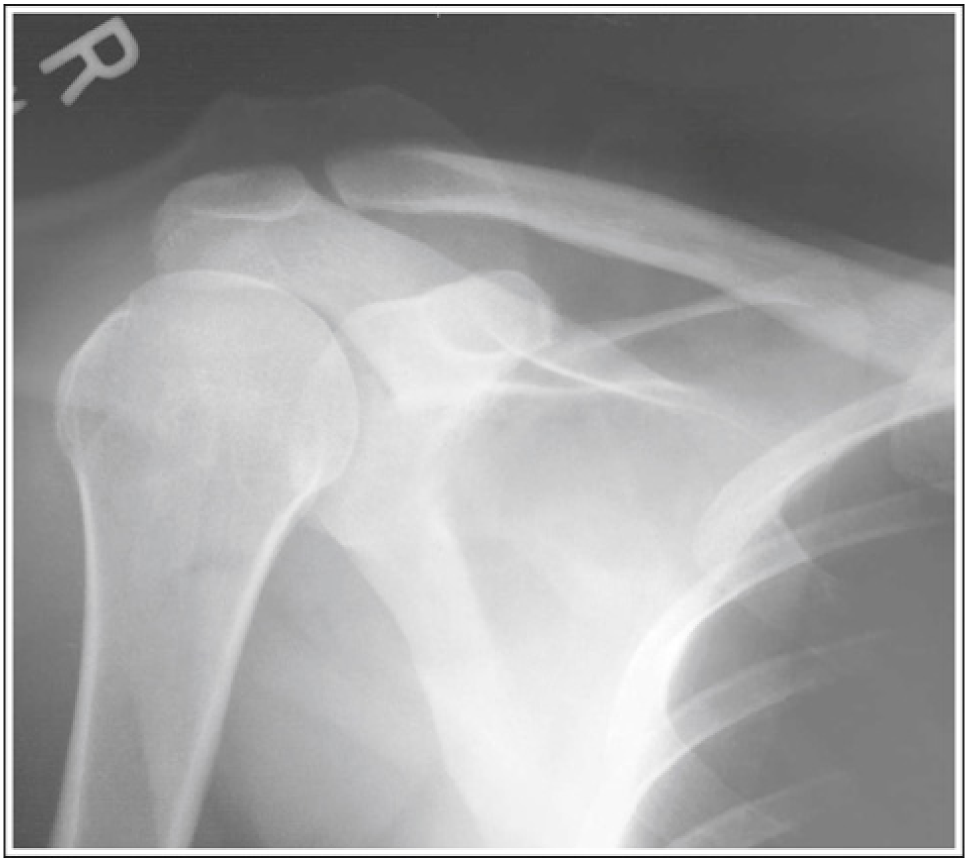


FIGURE 2.62 Computed radiography AP shoulder projection demonstrating a phantom image artifact.

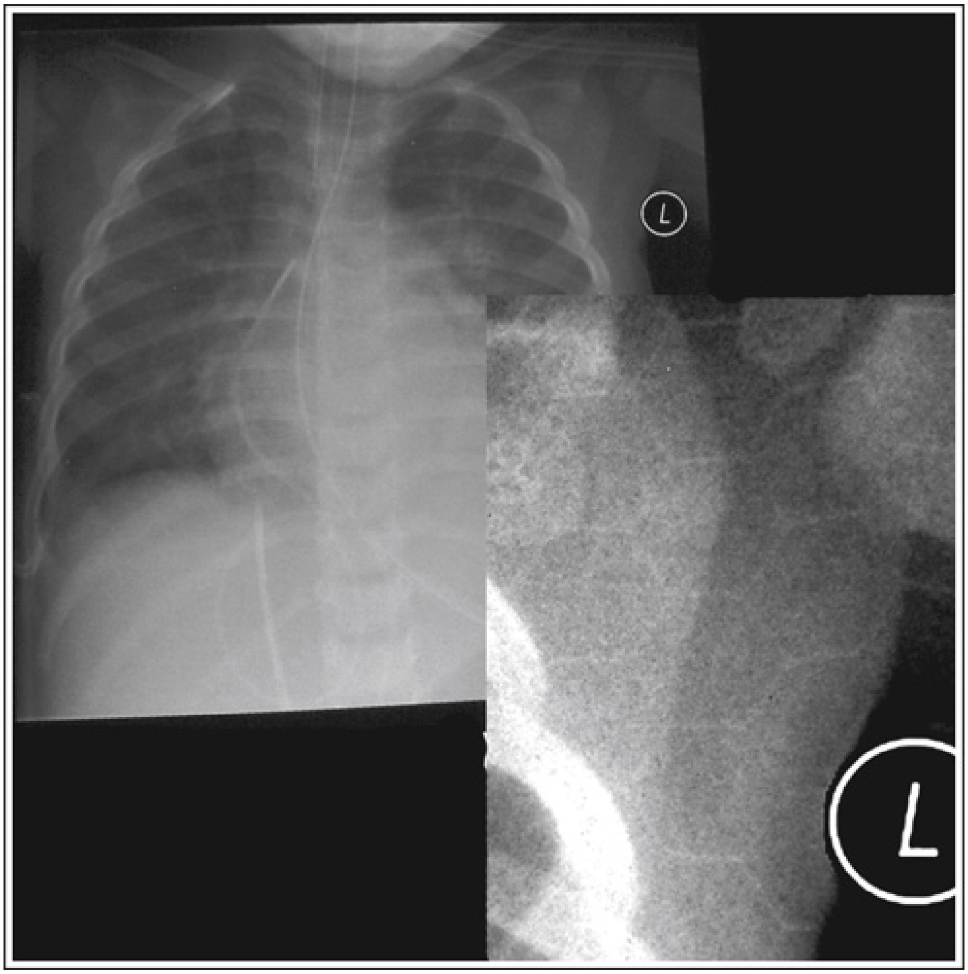


FIGURE 2.63 Computed radiography AP chest projection demonstrating honeycomb pattern overlying the projection. This was caused by the back of the cassette being positioned toward the CR for the exposure.

FIGURE 2.64 CareStream DRX-Revolution mobile AP chest projection taken with the IR reversed.

FIGURE 2.65 Computed radiography IP with scratches and dust on AP hip projection.

FIGURE 2.66 PA and lateral hand projections showing posterior displacement of the fourth metacarpal (MC) caused by a fracture.

2. Gather and organize the supplies (e.g., positioning aides, disposable gloves, radiation protection supplies) that will be needed, and determine the starting technical factors (kV, mAs, AEC) for the needed projections. Cover the positioning aids and IRs to protect them from contamination.
3. Determine the degree of patient mobility, alertness, and ability to follow requests. Can the patient be placed in a seated position or be rotated to one side? Can the arm or leg fully extend or flex? When the patient is asked to breathe deeply, can he or she follow the request? Can the patient control movement?

4. Assess the site of interest for physical signs of injury (swelling, bruising, deformity, pain). Understanding the degree of injury will help the technologist prevent further injury during the positioning process.
5. Determine whether positioning devices (e.g., slings, backboards, casts) and artifacts (e.g., heart leads, clothing, jewelry) may be removed and, if not, whether they will obscure the VOI on the ordered projections. If positioning devices or artifacts will obscure the area, consult with the radiologist or ordering physician about possible alternatives (e.g., taking a slight oblique instead of a true projection).
6. Set an optimal kV and mAs or AEC for the anatomic structure and projection being imaged. Technical adjustments may also be needed due to the increased photon absorption that may occur because of positioning devices, artifacts, additive or destructive patient conditions, or the SID or OID not being set at the routine settings. **Table 2.12** lists common technical adjustments needed when imaging trauma patients.

TABLE 2.12

Technical Adjustments for Trauma Patients

Immobilization Devices or Patient Condition	kV Adjustment	mAs Adjustment
Small to medium plaster cast	+5–7	+50%–60%
Large plaster cast	+8–10	+100%
Fiberglass cast (Fig. 2.67)	No adjustment	No adjustment
Inflated air splint	No adjustment	No adjustment
Wood backboard (Fig. 2.68)	+5	+25%–30%
Ascites (accumulation of fluid; see Fig. 2.34)		+50%–75%
Pleural effusion (fluid in pleural cavity)		+35%
Pneumothorax (air or gas in pleural cavity)	−8%	
Postmortem imaging of head, thorax, and abdomen (because of pooling of blood and fluid)		+35%–50%

Immobilization Devices or Patient Condition	**kV Adjustment**	**mAs Adjustment**
Soft tissue injury (used for foreign objects, such as slivers of wood, glass, or metal, embedding in the soft tissue and to demonstrate the upper airway)	−15% to 20%	

kV, Kilovoltage; *mAs*, milliampere-seconds.

FIGURE 2.67 Lateral lower leg projection with fiberglass cast.

FIGURE 2.68 AP hip projection taken through the backboard.

7. Obtain the requested projections. The technologist should attempt to fulfill the routine positioning guidelines for patient positioning, CR centering, IR and part orientation, and collimation when obtaining mobile and trauma projections. For patients who are unable to follow these requirements, adaptations to this setup can be made. Never force the patient into a position. Instead, adjust the CR and

IR. As long as the CR, part, and IR form the same alignments that are indicated for routine positioning, identical projections will result.

8. Use the smallest possible OID and increase the SID to compensate if a longer than routine OID is needed.
9. Use a grid if the patient part thickness is over 4 inches (10 cm) and over 60 kV is used. Higher grid ratios are recommended when the part thickness is above 22 cm, but they offer poor positioning latitude. When the positioning latitude is narrow because of the patient's condition or when the mobile unit is used, choose a parallel low-ratio grid to allow for the greatest positioning error latitude. Evaluate the alignment of the CR and grid:
   - Is the CR aligned accurately with the center of the grid?
   - If a CR angle is used, is it angled with the grid lines?
   - Is the grid level?
   - Is the SID within the grid's focusing range?
   - Is the correct side of the grid facing the CR?
   - If a focused grid is used, is the body part being imaged in the center of the grid?
10. Use good radiation protection practices. Ask female patients if there is any chance they could be pregnant. Never assume that other staff members have asked. Collimate tightly and provide those assisting with patient holding during the exposure with aprons and lead gloves. For recumbent patients, projections of the extremity should not be taken by placing the IR and part on the patient's torso unless it is the only means of obtaining accurate positioning. If this is the case, always place a lead apron between the IR and torso. Not all the radiation directed toward the IR is absorbed; high-energy

beams will exit through the back of the IR, exposing structures beneath.

11. Never leave a confused patient or a trauma patient unattended in the imaging room.
12. Process the projections and evaluate them for positioning and technical accuracy. Determine whether repeat projections are needed and how much adjustment will be required. When the trauma is severe, all the evaluating guidelines listed in the procedural sections of this textbook may not be evident (**Fig. 2.69**). This is one of the reasons why I have often described more than one anatomic relationship to indicate accurate positioning in the evaluating guidelines.
13. Repeat any necessary projections.
14. Return the patient to the emergency room or, if the projections were taken with the mobile unit, replace the bed, monitoring devices, and personal items to the positions they occupied when you entered the room or to positions that make the patient most comfortable.

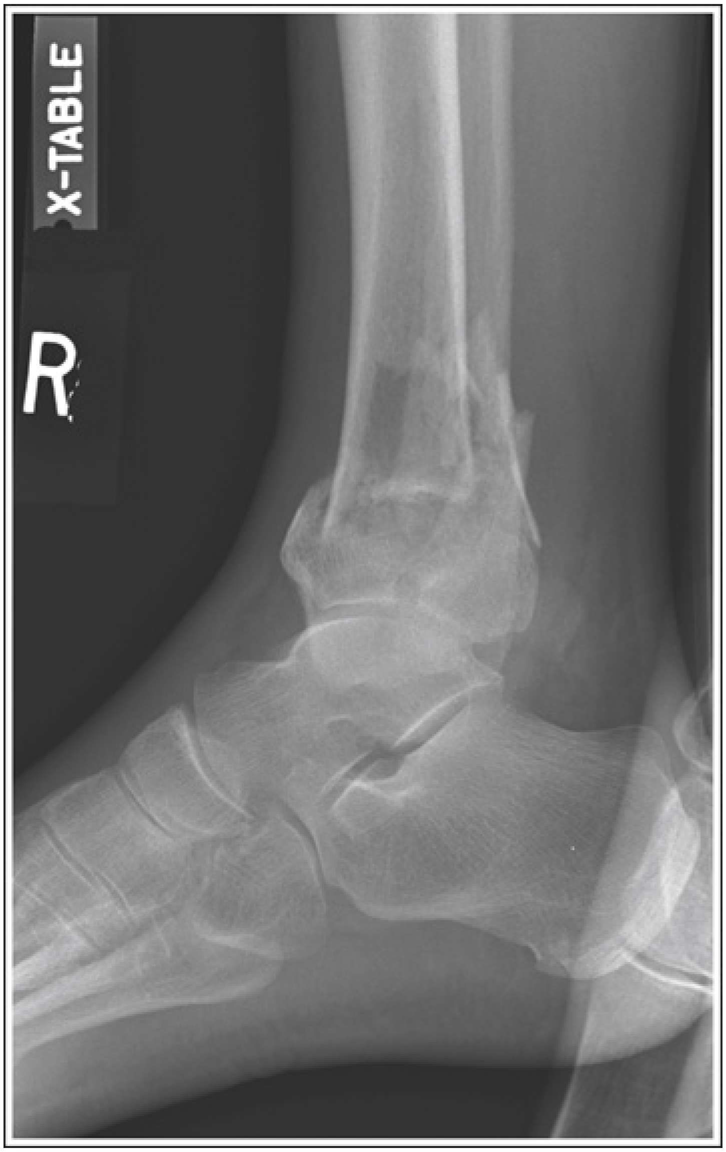


FIGURE 2.69 Trauma lateral ankle projection where the tibial-fibular relationship cannot be used to determine accuracy of the positioning, but the domes of the talus are well visualized and indicate that the ankle was well positioned.

15. Disinfect all equipment and devices used during the procedures.

Guidelines for Aligning CR, Part, and IR

Whenever possible, set up the routinely used CR, part, and IR alignments as you would for the routine projections. The word *part* with regard to alignment refers to the specific plane, imaginary line, or anatomic structure used to position the patient with the CR and IR in routine positioning.

Lateral Projections

Routine lateral foot projections require that the foot's lateral surface be aligned parallel to the IR and the CR be aligned perpendicular to the part and the IR. In this situation, the lateral foot surface is the part, because this is what is used to position the foot in relation to the CR and IR. If the lateral foot projection is taken on the imaging table, the patient will externally rotate his or her leg until the lateral foot surface is parallel to the IR, and the CR will be aligned perpendicular to the IR and part (**Fig. 2.70**). If the lateral foot projection is taken in a standing position, the IR will be positioned vertically and the CR horizontally. Even though the setup appears different, the CR, part, and IR alignments are the same as in the previous setup. The lateral foot surface is positioned parallel to the IR, and the CR is perpendicular to the IR and lateral foot surface. Often, when a cross-table projection is created, the path that the CR takes is opposite. For a routine tabletop lateral foot projection, a mediolateral projection is performed, whereas a lateromedial projection is used for cross-table projections. To obtain identical projections for both pathways, the CR, part, and IR must maintain the same alignment. This means that the lateral surface of the foot must still be positioned parallel to the IR for a lateromedial projection, even if this surface is not placed directly adjacent to the IR. For a lateral foot projection, this will require the medial aspect of the heel to be positioned slightly away from the IR (**Fig. 2.71**).

FIGURE 2.70 Accurate tabletop positioning for a mediolateral foot projection.

If a patient arrives in the radiology department in a wheelchair and is unable to move to the imaging table for the lateral foot projection, the projection can be obtained with the patient remaining in the wheelchair. First, align the lateral foot surface with the IR and then align the CR perpendicular to the IR and lateral foot surface. Again, because the relationships between the CR, IR, and part are the same as in the two previous setups, the resulting projection will be identical (**Fig. 2.72**).

Oblique Projections

For trauma oblique projections, begin by aligning the CR with the plane, line, or anatomic structure that is used for an AP projection of the part being imaged. Next, adjust the CR in the direction needed to set up the correct alignment between the CR and structure. Because the degree of angulation in which patients are rotated for oblique projections is always referenced from the AP-PA projection, the amount of angle adjustment would be the same as the required degree of obliquity. For a routine internal AP oblique

elbow projection, the CR is aligned at a 45-degree angle with an imaginary line connecting the humeral epicondyles (the medial epicondyle is placed farther from the tube than the lateral). To obtain the same projection in a patient who is unable to rotate his or her arm, the technologist first positions the CR perpendicular to the line connecting the epicondyles and then adjusts the angle 45 degrees medially, positioning the medial epicondyle farther from the x-ray tube than the lateral epicondyle. The IR would then be aligned as close to perpendicular to the CR as possible (**Fig. 2.73**).

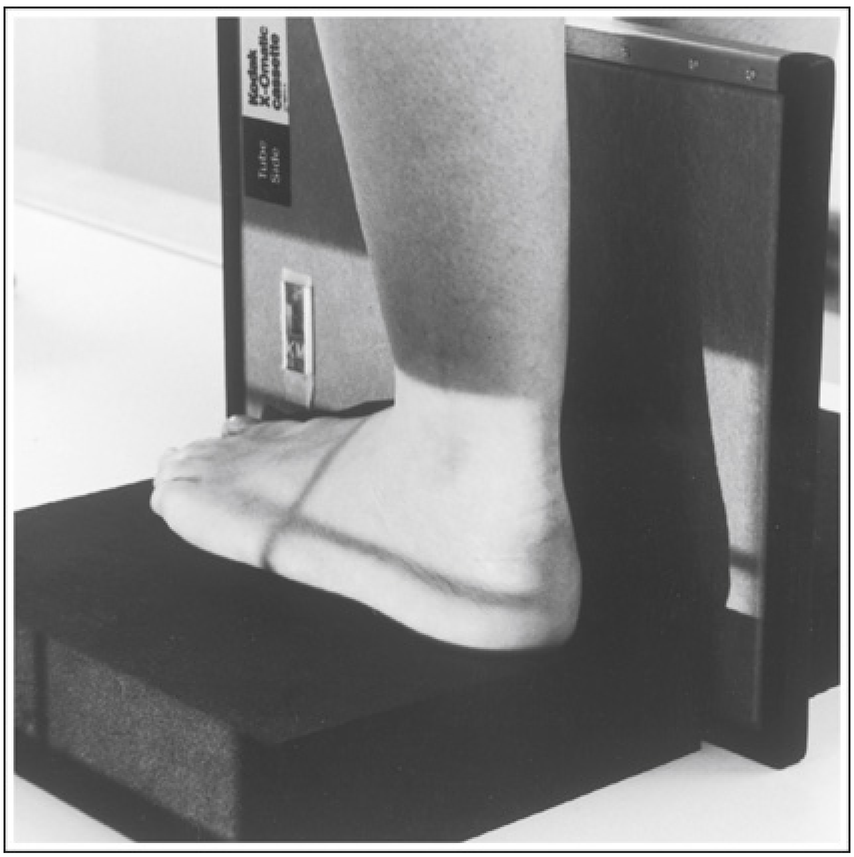


FIGURE 2.71 Accurate standing positioning for a lateromedial foot projection.

FIGURE 2.72 Accurate wheelchair positioning for a mediolateral foot projection.

Alignment of CR and Part Versus CR and IR

To obtain open joint spaces, clearly see fracture lines, or obtain specific anatomic relationships, the alignment of the CR with the part must be accurate. Although IR alignment with the CR and part is important to prevent elongation distortion, it does not have an effect on the anatomic relationships that are demonstrated. After the CR and part are accurately aligned, the IR should be positioned as close to perpendicular to the CR as possible. If the CR is not positioned perpendicular to the IR, the resulting projection will demonstrate elongation in the direction toward which the

CR was angled, but the anatomic alignment of the structures are demonstrated as required for the projection. The more acute the CR and IR angle, the greater the elongation. In this situation, the IR will need to be offset in the direction toward which the CR is angled more than what would occur if the IR were positioned perpendicular to the CR. Because of this offset, careful attention should be given to centering the center of the IR to the CR.

FIGURE 2.73 Accurate trauma positioning for an internal AP oblique elbow projection.

Imaging Long Bones

To demonstrate long bones with the least amount of distortion and obtain optimal anatomical alignment, the CR is aligned perpendicular and the IR parallel with the bone's long axis (**Fig. 2.74A**; also see **Fig. 1.49**). When imaging a long bone where the patient is unable to position the bone so its long axis is parallel with the IR, the alignments created between the CR, IR, and bone determine the degree and type of distortion and the anatomical relationships demonstrated on the resulting projection. **Fig. 2.74B** was obtained with the distal forearm in a PA projection and elevated so the forearm's long axis was at a 20-degree tilt with the IR and the CR aligned perpendicular with the IR. This setup is the least desired because it will produce the greatest foreshortening and poorest anatomic alignment at the joints. Compare the forearm length and the anatomic alignments of the elbow bones between **Fig. 2.74A and B**. The forearm image in **Fig. 2.74C** was obtained using the law of isometry (**Fig. 2.75**). The law of isometry indicates that the CR should be set at half of the angle formed between the object and IR to minimize foreshortening. For example, if the patient's knee cannot be fully extended for an AP femur projection, causing the femur to be at a 30-degree angle with the IR and the distal femur positioned at a larger OID than the proximal femur, the CR should be angled 15 degrees toward the proximal femur. This setup provides a projection with reduced foreshortening and improved, although not optimal, anatomic alignment of the joints. Compare the anatomic alignment of the elbow joints in **Fig. 2.74A–C**. Note that elbow joint is open in **Fig. 2.74A** and is closed in **Fig. 2.74B and C**. The joints will not demonstrate optimal anatomical alignment when the law of isometry is used because the CR is not perpendicular with the long bone for this setup and the diverged x-rays recording the joints are not at the same angles as they are when the CR is perpendicular. **Fig. 2.74D** was obtained with the forearm aligned at a 20-degree tilt with the IR and

the CR aligned perpendicular to the forearm (see **Fig. 1.49D**). This setup produces the same anatomic alignments of the bones at the elbow joint as was obtained for the ideal setup in **Fig. 2.74A**, but because the wrist was positioned at a greater OID than the elbow (20-degree forearm to IR tilt), the forearm demonstrates elongation.

FIGURE 2.74 Creating optimal projections of long bones. (A) Optimal CR, forearm, and IR alignment. (B) Foreshortening of forearm due to part tilting. (C) Forearm obtained using the law of isometry. (D) Elongated forearm obtained with CR perpendicular with part and IR angled.

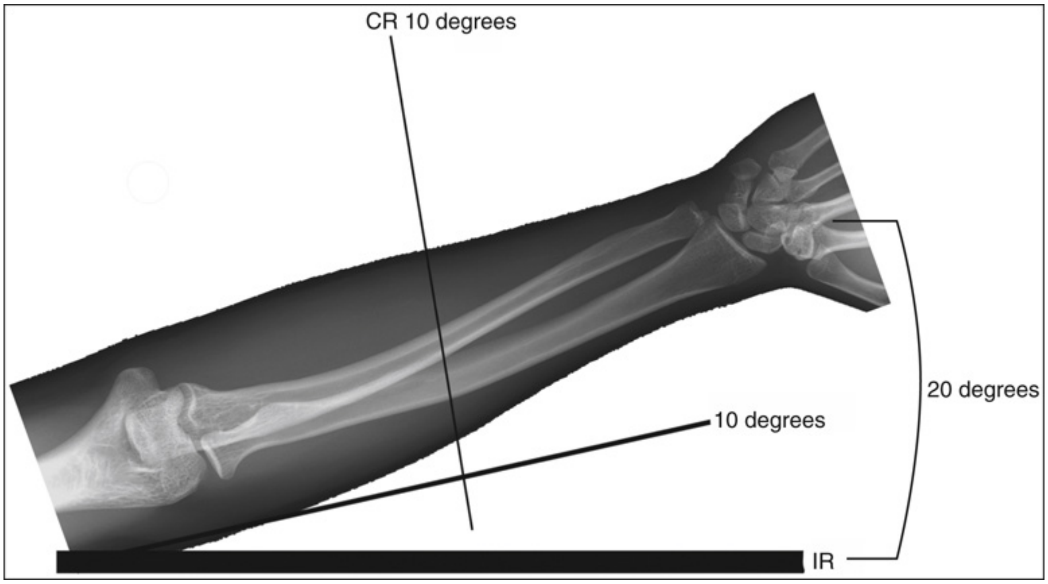
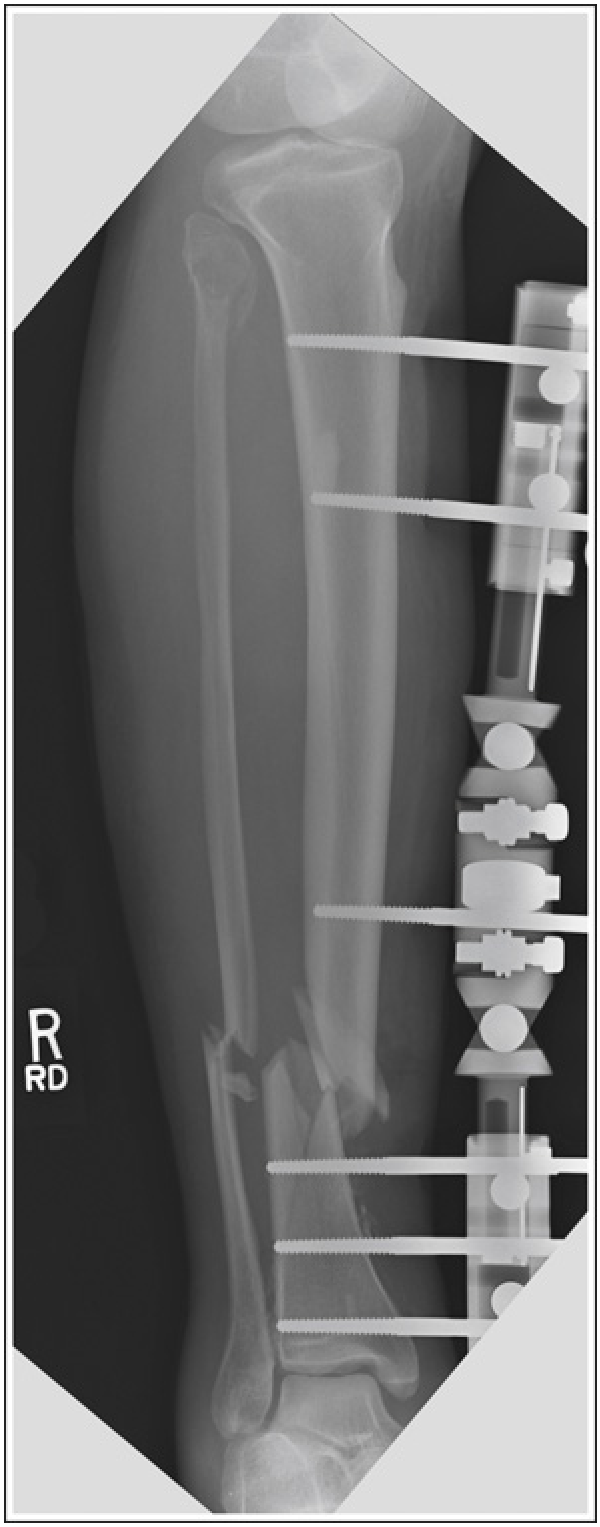


FIGURE 2.75 Using the law of isometry to image long bones.

Whether the ideal setup for a long bone that cannot be positioned with its long axis parallel with the IR is obtained using the law of isometry (see **Fig. 2.74C**) or a perpendicular CR (see **Fig. 2.74D**), is best decided by using the setup that will optimally demonstrated the VOI. The law of isometry demonstrates the least foreshortening, and a perpendicular CR best demonstrates the anatomic relationships at the joints.

When imaging long bones that require both joints to be included on the same projection, but the joints cannot be positioned in the true projection simultaneously because of a fracture, the joint closest to the fracture is positioned in the true projection (**Fig. 2.76**).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RD

FIGURE 2.76 Trauma AP lower leg projection with the joint closest to fracture demonstrating accurate positioning.

Pediatric Imaging

The images of pediatric patients are very different from those of adults and from each other during the various stages of bone growth and development (**Fig. 2.77**). Bones throughout the body enlarge through the deposits of bone at cartilaginous growth regions, and long bones lengthen by the addition of bone material at the epiphyseal plate. Cartilaginous spaces and epiphyseal plates exist throughout the skeletal structure. They appear as darker shaded spaces and lines on projections, and may look similar to an irregular fracture or joint space to those unfamiliar with pediatric imaging. The appearances of these spaces and lines are reduced as the child develops, until early adulthood, when they are replaced by bone and are no longer visible on the projection. Round bones, such as the carpal and tarsal bones, are rarely formed at birth and therefore are not demonstrated on projections of neonatal and very young pediatric patients. Because of this continual state of development, some anatomic relationships described in the imaging analysis sections may not be useful for determining accurate positioning for the pediatric patient. It is beyond our scope here to explain all the differences that could be demonstrated at different growth stages for each projection included in this text. When evaluating pediatric projections for proper anatomic alignment, use only the analysis guidelines that describe bony structures that are developed enough to use. For example, the section on PA wrist projection analysis describes the alignment of the carpal bones and metacarpals to determine accurate positioning. The carpal bone alignment cannot be used to evaluate young pediatric wrists, because all the

carpal bones are not formed but the metacarpals can be used to determine positioning accuracy.

Technical Considerations

Pediatric imaging requires lower technical values (kV and mAs) when compared with those for adults. **Box 2.2** lists guidelines to follow when selecting technical values for pediatric patients.

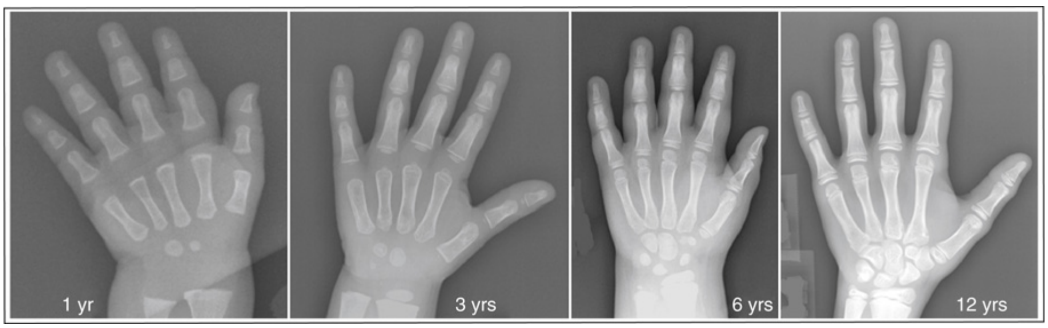


FIGURE 2.77 Pediatric PA hand and wrist projections at different ages of skeletal development.

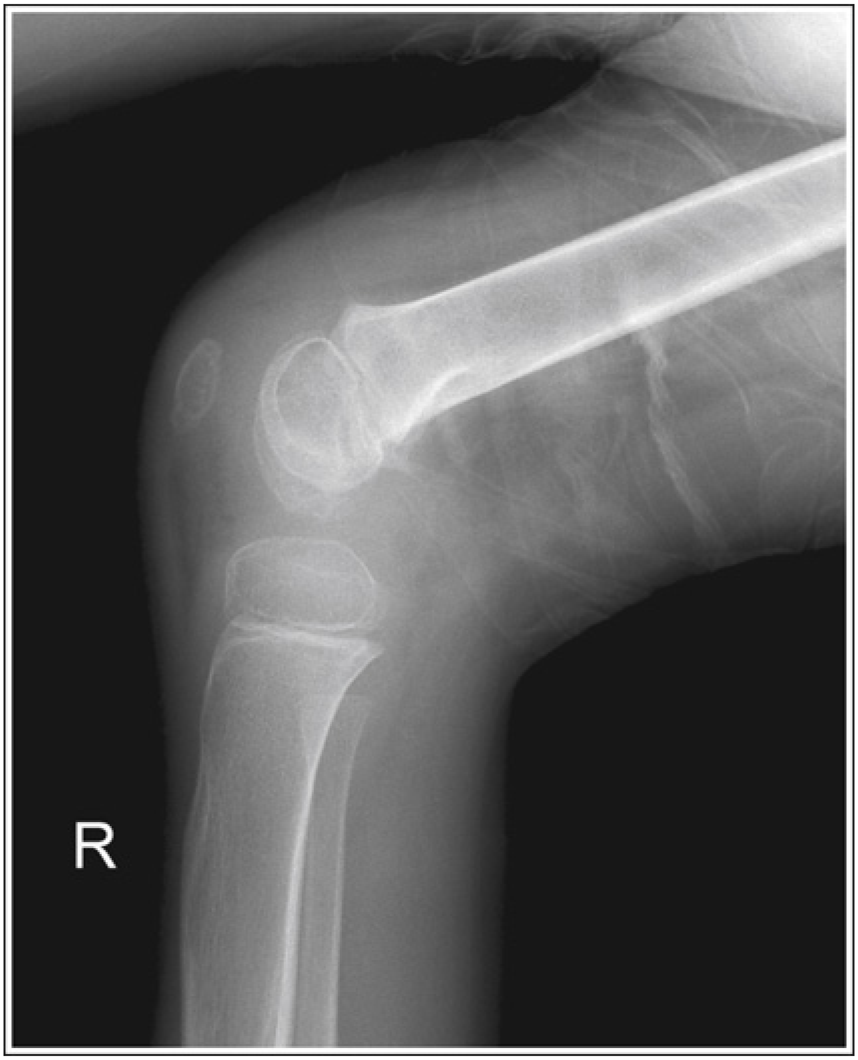


FIGURE 2.78 Lateral knee projection showing clothing artifacts around the distal femur on pediatric patient.

Box 2.2 Guidelines for Setting Technical Factors for Pediatric Patients ***AEC*****, Automatic exposure control;** ***EI*****, exposure index;** ***IR*****, image receptor;** ***kV*****, kilovoltage;** ***mAs*****, milliampere-seconds.**

- Choose a high mA and short exposure times to prevent patient motion.
- Only use a grid if the part thickness measures over 4–5 inches (10–13 cm).
- Follow the best practices guidelines for AEC usage closely, as fast enough exposure times and chamber coverage may limit use, or use a thickness measurement driven manual technique.
- Lower IR exposure by adjusting kV and mAs over that used for adults to maintain ideal IE levels.

Clothing Artifacts

Because lower kV is used in pediatrics, clothing artifacts may be problematic in neonates and smaller children (**Fig. 2.78**). The kV used may not be high enough to obscure creases or folds, particularly in unlaundered material or flame-resistant clothing. It is best to image children without upper clothing or with a tee shirt when modesty is an issue. Skinfolds of neonates may also cause artifacts when they overlie the chest.

Positioning Guidelines

When imaging pediatric patients, do not palpate for the pubic symphysis, because it is not fully formed and they are taught that no one should touch their “private areas.” Instead, use the greater trochanters as they are at the level of the superior border of the pubic symphysis.

Obese Patient Imaging

As Americans become increasingly obese, it has a direct impact on the health care system and imaging departments because these individuals have

an increased incidence of diabetes, heart disease, and certain types of cancer, and there is increasing popularity of bariatric surgery to help manage this condition. The challenges facing technologists as they image obese patients include transporting and accommodating larger patients on the current equipment, and difficulties in acquiring quality projections. The following are considerations for imaging this population.

1. Obese patients often feel unwelcome in medical settings, where they encounter negative attitudes, discriminatory behavior, and a challenging physical environment. The emotional needs of these patients must be considered when they are imaged. Avoid making remarks about their size, being mindful of terms used such as “big” when referring to special equipment needs or requests for “lots of help” when transferring the patient.
2. Patient weight and body diameter are factors that should be evaluated before transporting the patient to the department or performing the examination. Use this information to determine whether the patient's weight exceeds any of the equipment weight limits, including waiting room chairs or support structures, or whether his or her diameter exceeds the wheelchair or cart dimensions.
3. Avoid injury to the patient and personnel by making certain that enough people are available to assist if the patient requires moving before or during the procedure. Use moving devices, such as table sliders and lifts, whenever possible.
4. Determine how the positioning procedure (IR cassette size, CW-LW position of IR) will need to be adjusted from the routine to accommodate the increased structure size. For example, to include the entire abdomen on a morbidly obese patient may require a

separate IR for each of the four abdominal quadrants, instead of one for the top and bottom.

5. Obese patients have inherently low subject contrast because their muscles have lost strength and have become the consistency of fat, so technical values must be set to enhance subject contrast while producing the lowest possible patient dose to produce an image with sufficient image contrast.

Technical Considerations

Thicker patients attenuate more of the primary x-ray photons than thin patients, requiring the technologist to increase mAs and/or kV to compensate for the exposure loss that would result if a change were not made. Thicker patients also demonstrate a higher SNR reaching the IR, causing a loss in contrast resolution. For example, a typical abdominal projection taken on a patient measuring 20 cm will demonstrate a SNR of 3:1, meaning that 75% of the photons striking the IR are scattered photons that carry little or no useful information. For larger patients, the ratio in the abdomen can approach 5:1 or 6:1 (83% to 86%).

When determining how to adjust the technique for a thicker patient, the technologist must consider the effect that the change will have on patient dose and contrast resolution. As long as the kV is set to provide adequate demonstration of subject contrast throughout the part, increasing the mAs will generate enough x-rays to provide more IR exposure. *As a general rule, for every 4 cm of added tissue thickness, the mAs should be doubled to maintain IR exposure.* This technique adjustment will have a significant increase on patient dose because the increase in dose is directly proportional to the mAs increase. It will also demonstrate lower contrast because the amount of scatter radiation produced will increase with increased thickness.

Another technique adjustment option is to increase the kV. This will increase the penetration ability of the photons, resulting in more of them reaching the IR and increasing IR exposure. *As a general rule, for every centimeter of added tissue thickness, the kV is adjusted by 2 kV.* This option will increase patient dosage, but not directly or nearly as much, as with mAs. The drawback with using kV is that it lowers subject contrast visualization and will increase the amount of scatter radiation that will be directed toward the IR.

For best results when adjusting technique for a thick patient, the kV should be set higher than optimal, to maintain penetration and reduce radiation dose, but should not exceed a value that will result in the scatter fogging being detrimental to the quality of the projection. After kV value maximum has been attained, additional adjustments are made with mAs.

Scatter Radiation Control

One of the biggest obstacles when imaging the obese patient is controlling scatter radiation enough to provide a projection that has sufficient contrast resolution. This is accomplished by using very aggressive, tight collimation, using a high-ratio grid, or using an air-gap technique.

1. Tight collimation is often difficult when imaging obese patients because the collimator's light field demonstrated on the patient does not represent the true width and length of the field set on the collimator. The thicker the part being imaged, the smaller the collimator's light field that appears on the patient's skin surface. On a very thick patient, it is difficult to collimate the needed amount when the light field appears so small, but on these patients, tight collimation demonstrates the largest improvement in the visibility

of recorded details. Learn to use the collimator guide to determine the actual IR coverage.

2. Many projections, such as the inferosuperior (axial) shoulder projection, which do not require a grid on the thinner patient, will need to be performed using a grid. Measure all structures and use a grid when the part thickness is more than 4 inches (10 cm). Higher grid ratios are recommended when the part thickness is above 22 cm.

Focal Spot Size

When using a small focal spot, the mA is typically limited to 300 mA or less. Using such a small focal spot may not be feasible when imaging an obese patient, because it would require a long exposure time to achieve the needed IR exposure and motion may result.

Automatic Exposure Control

Select a high mA to avoid long exposure times and the potential motion it causes. Also, adjust the backup timer to 150% to 200% of the expected manual exposure time.

1. When possible, remove overlapping soft tissue from the area being imaged to decrease the thickness of the tissue being penetrated. **Fig. 2.79** demonstrates an AP pelvis projection in which the soft tissue overlapping the hips could have been pulled superiorly and held with tape or by the patient, decreasing the soft tissue over the hips and allowing them to be demonstrated more effectively. Overlapping breast and arm tissue can also be held away from the shoulder during inferosuperior (axial) shoulder projections to decrease thickness and improve detail visibility.

2. Use palpable bony structures to position the patient and to collimate whenever possible. Remember, the skeletal structure does not increase in size with an increase in the soft tissue surrounding it. **Fig. 2.80** shows a bone scan on an obese patient that clearly illustrates this point. Using palpable bony structures to determine where structures are located whenever possible will help you position accurately and collimate more specifically to the structures of interest.

FIGURE 2.79 AP pelvis projection showing overlapping soft tissue, preventing uniform density of hip joints and proximal femurs.

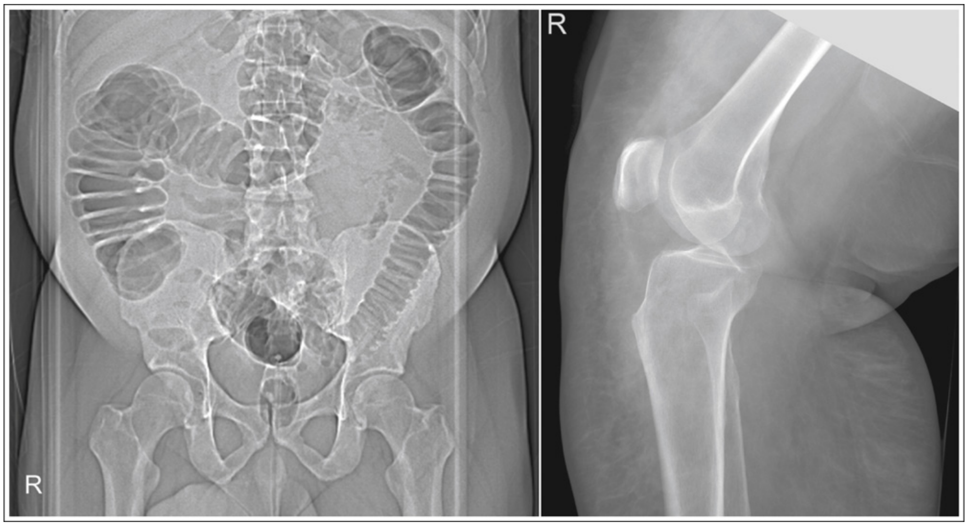


FIGURE 2.80 AP abdomen and lateral knee projections on an obese patient to show placement of skeletal structure within surrounding soft tissue.

When the soft tissue thickness prevents palpation of bony structures, use signs such as depressions or dimples in the soft tissue that suggest where the bony structures are located. Observe closely how the patient is positioned for each projection, so if a repeat is needed, you can adjust the amount needed from the original positioning.

Chapter 3: Image Analysis of the Chest and Abdomen

Correction

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Identify the required anatomy on all chest and abdominal projections.
- Describe how to position the patient, image receptor (IR), and central ray (CR) properly for adult and pediatric chest and abdominal projections.
- State the technical data used in chest and abdominal projections.
- List the image analysis guidelines for accurately positioned adult and pediatric chest and abdominal projections.
- State how to reposition the patient when chest and abdominal projections with poor positioning are produced.
- Discuss how to determine the amount of patient or CR adjustment required to improve poor positioning on chest and abdominal projections.
- State how the patient and CR are positioned to demonstrate air and fluid levels best within the pleural cavity. Explain how this detection is affected on an AP-PA chest projection if the patient is placed in a supine or partial upright position.
- State the purpose and proper location of the internal devices, tubes, and catheters demonstrated on adult and pediatric AP chest and abdominal projections.

- Explain why a 72-inch (183-cm) source–image receptor distance (SID) is routinely used for chest projections.
- List the chest dimensions that expand when the patient inhales and the conditions that prevent full lung expansion.
- Describe scoliosis, and identify a chest projection of a patient with this condition.
- Describe methods of identifying the right and left hemidiaphragms on lateral chest projections.
- Explain the location of the liver and discuss how its location affects the height of the right hemidiaphragm.
- Discuss how the patient is positioned for a lateral decubitus chest projection to rule out pneumothorax and pleural effusion.
- Explain how neonates' lungs develop and change as they grow and how CR centering is adjusted because of these changes.
- Describe the location of the psoas muscles and kidneys.
- Discuss how technique is adjusted for chest and abdomen projections of patients with additive and destructive conditions. Explain why this adjustment is required.
- Explain why a patient is positioned in the upright or lateral decubitus position for at least 10 to 20 minutes before the abdominal projection is taken.
- Describe why it is necessary to center differently for female and male patients when positioning for an AP abdominal projection.
- State why it is necessary for the diaphragm to be included in all upright and lateral decubitus abdominal projections.

KEY TERMS

augmentation mammoplasty

automatic implantable cardioverter defibrillator (ICD)

body habitus

central venous catheter (CVC)

cortical outline

endotracheal tube (ETT)

intraperitoneal air

kyphosis

mammary line

pacemaker

pleural drainage tube

pleural effusion

pneumectomy

pneumothorax

pulmonary arterial catheter

scoliosis

umbilical artery catheter (UAC)

umbilical vein catheter (UVC)

vascular lung markings

IMAGE ANALYSIS GUIDELINES

CHEST

Technical Data

See **Table 3.1** and **Box 3.1**.

Source-to-IR Distance

Because the heart is situated at a large object–image receptor distance (OID) for chest projections, a 72-inch (183-cm) source–image receptor distance (SID) is used to decrease the magnification of the heart and better demonstrates the lung details.

Vascular Lung Markings

Vascular lung markings are scattered throughout the lungs and are evaluated for changes that may indicate pathology. To visualize these markings on chest projections, the lungs must be fully expanded. To obtain maximum lung aeration in a patient who is able to follow instructions, take the exposure after the second full inspiration. For the unconscious patient, observe the chest moving and take the exposure after the patient takes a deep breath.

Ventilated Patient

For the patient who is being ventilated with a conventional ventilator, observe the ventilator's pressure manometer to determine when full lung aeration has occurred. The exposure should be taken when the manometer digital bar or analog needle moves to its highest position. If a high-frequency ventilator is being used, the exposure may be made at any time, because this ventilator maintains the lung expansion at a steady mean pressure without the bulk gas exchange of the conventional type.

TABLE 3.1

SID, Source–image receptor distance.

[a] kV listed is for digital radiography systems.

[b] Use grid if patient part thickness measures 4 inches (10 cm) or more.

Box 3.1 Chest Technical Data Guidelines

- The facility's identification requirements are visible.
- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Lung markings, diaphragm, heart borders, hilum, greater vessels, and bony cortical outlines are sharply defined.
- Contrast resolution is adequate to demonstrate the thoracic vertebrae, mediastinal structures, vascular lung markings throughout the lung field, fluid-air levels, and internal monitoring apparatus, when present.
- No quantum mottle or saturation is present.
- Scatter radiation has been kept to a minimum.

- There is no evidence of preventable artifacts, such as undergarments, necklaces, gown snaps, or removable external monitoring tubes or lines.

Lung Conditions Affecting Vascular Lung Marking Visualization

Pneumothorax and Pneumectomy

A pneumothorax (**Fig. 3.1**) or pneumectomy (**Fig. 3.2**) may be indicated if no lung markings are present, whereas excessive lung markings may suggest conditions such as fibrosis, interstitial or alveolar edema, or compression of the lung tissue. When selecting the technical factors (mAs and kV) to be used for chest projections, if a pneumothorax is suspected, decrease the kV 8% from the routinely used setting (see **Table 3.1**).

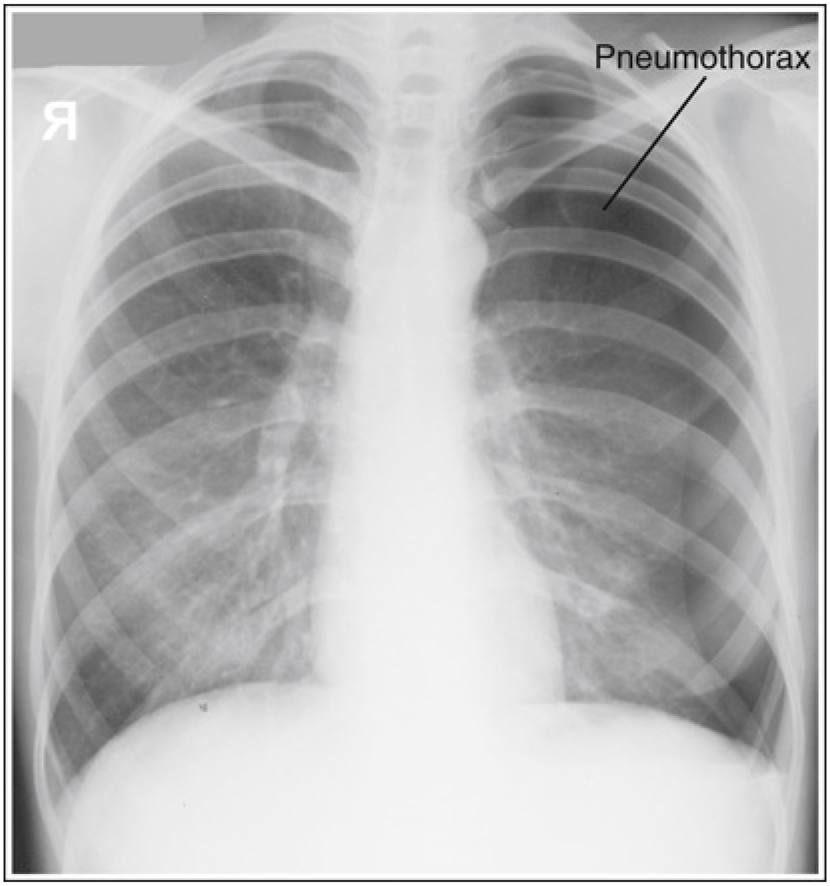


FIGURE 3.1 PA chest demonstrating a pneumothorax.

When a pneumectomy is indicated, do not select the automatic exposure control (AEC) chamber that is positioned beneath the removed lung or saturation of the opposite lung may present (**Fig. 3.3**).

Pleural Effusion

To demonstrate precise fluid levels when a pleural effusion is suspected, chest projections are taken with the patient upright and the x-ray beam horizontal. With this setup the air rises and the fluid gravitates to the lowest position, creating an air-fluid line or separation. This separation can be identified as an increase in brightness and an absence of lung markings on

the projection wherever the denser fluid is present in the lung field (**Fig. 3.4**).

If the patient is positioned only partially upright, the fluid line will slant, like water in a tilted jar. To demonstrate the true fluid line in this position, the central ray (CR) must remain horizontal, even though it will result in foreshortening of the chest structures in the anteroposterior (AP) and posteroanterior (PA) projections. When the patient is supine, the fluid is evenly spread throughout the lung field, preventing visualization of fluid levels in the AP projection because a horizontal beam cannot be used.

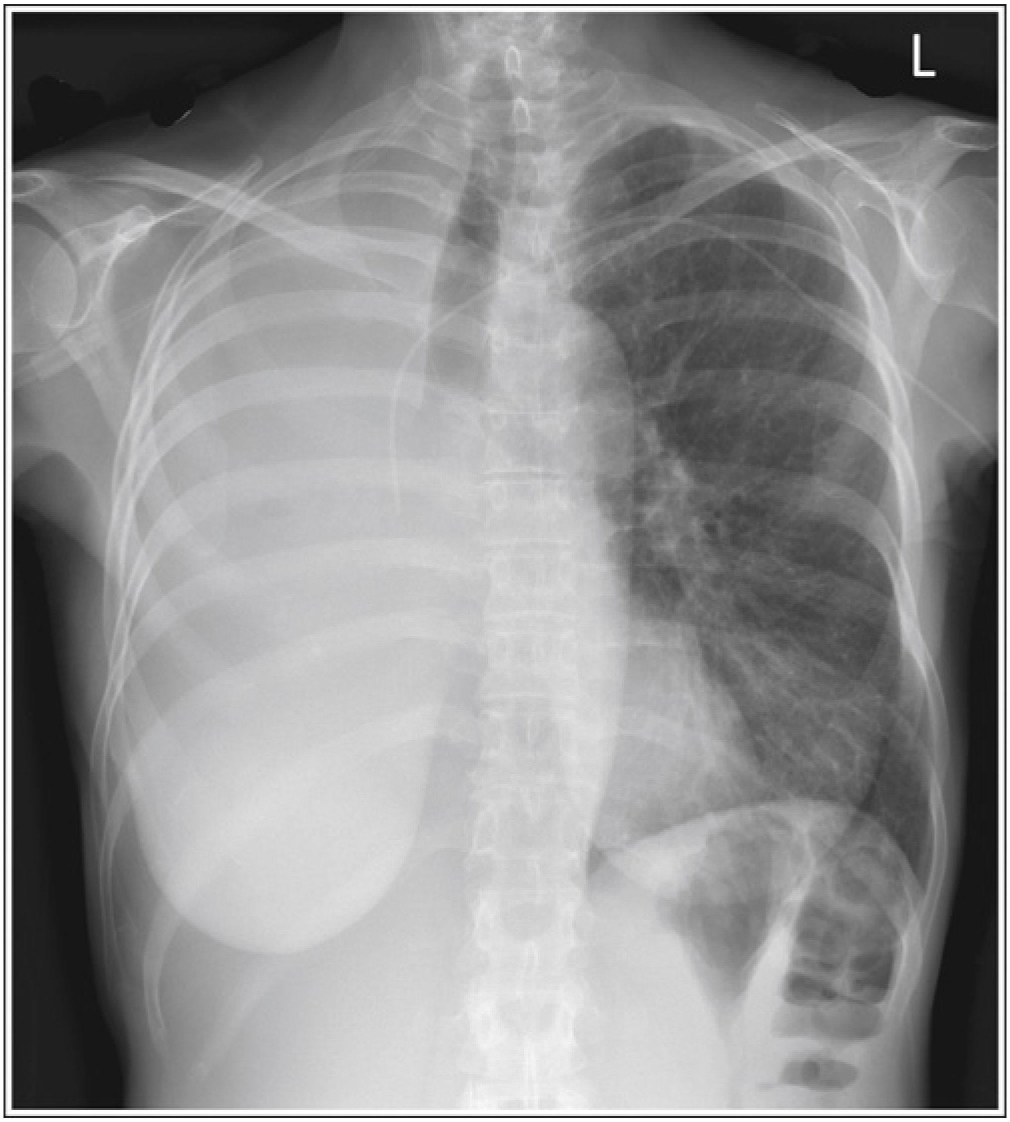


FIGURE 3.2 AP chest on patient with right-sided pneumectomy.

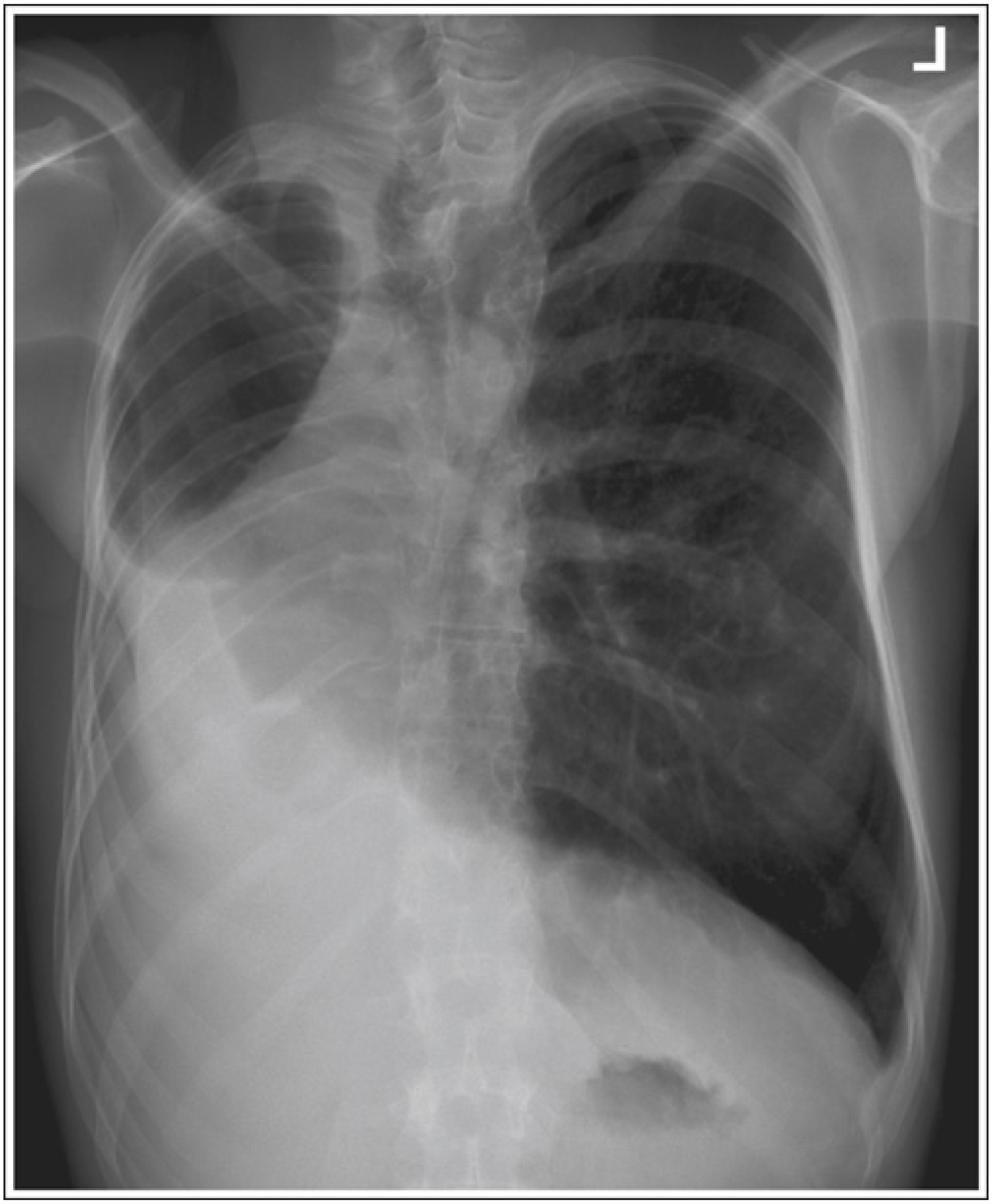


FIGURE 3.3 PA chest with right-sided pneumectomy taken with right AEC chamber activated.

If pleural effusion is suspected, increase the mAs by 35% over the routinely used setting (see **Table 3.1**).

Free Intraperitoneal Air

Along with the upright AP and AP left lateral decubitus abdomen projections, the erect chest projection is also an excellent method of discerning the presence of free intraperitoneal (within abdominal cavity) air because it will closely outline the diaphragm (**Fig. 3.5**). To demonstrate the air, when present, the exam must be taken with the patient upright and the CR horizontal.

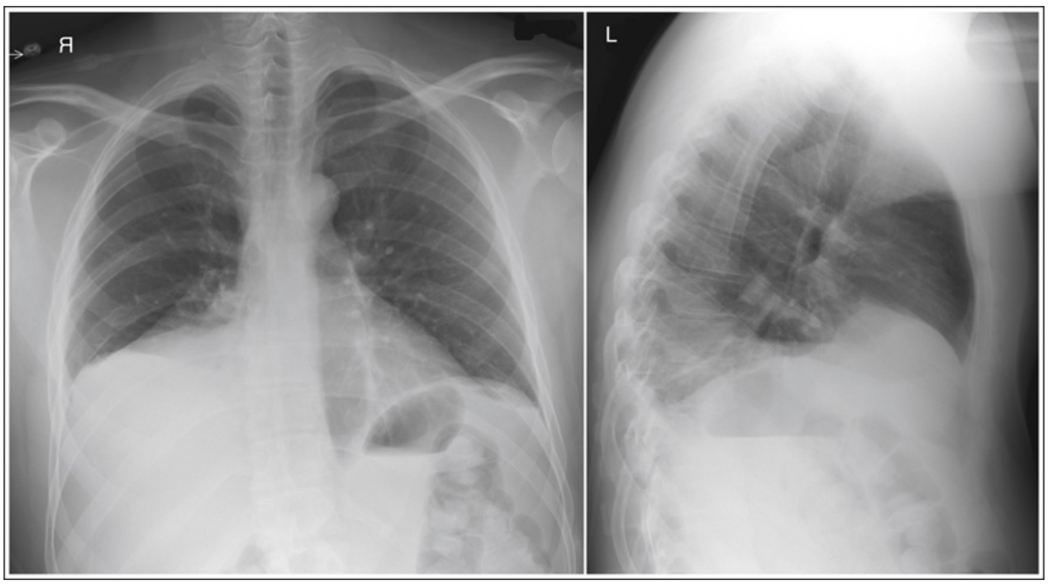


FIGURE 3.4 PA and lateral chest on patient with right-sided pleural effusion.

Chest Devices, Tubes, Lines, and Catheters

Familiarizing yourself with the accurate placement of the devices, lines, and catheters that are seen on chest projections will provide the information needed to understand when special care must be taken during positioning, and to identify when proper technique was used to visualize them and when poor placement is suspected (**Table 3.2**). **Fig. 3.6** demonstrates poor placement of the pulmonary arterial line, because it was not advanced to the

pulmonary artery. When a chest projection is taken to determine the accuracy of line placement, it is within the technologist's scope of practice to inform the radiologist or attending physician immediately when a mispositioned device, line, or catheter is suspected.

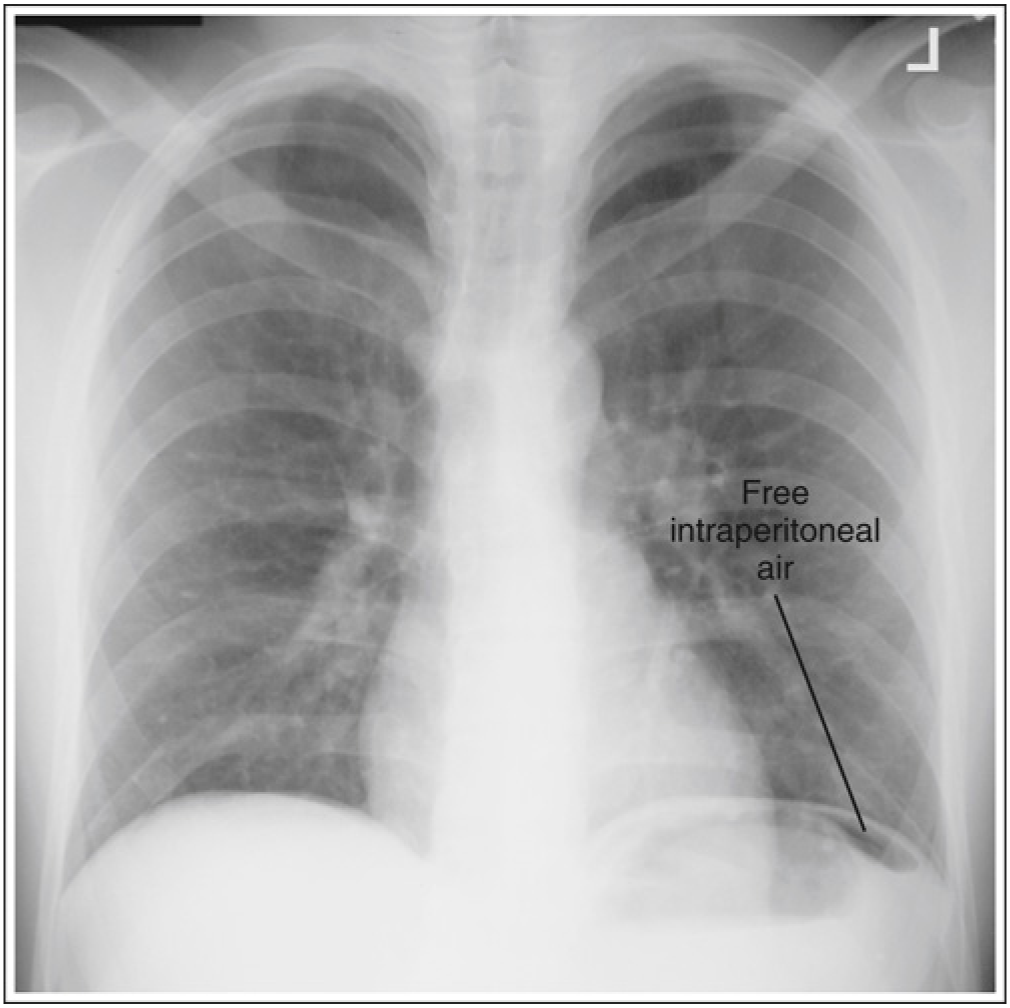


FIGURE 3.5 PA chest demonstrating free intraperitoneal air.

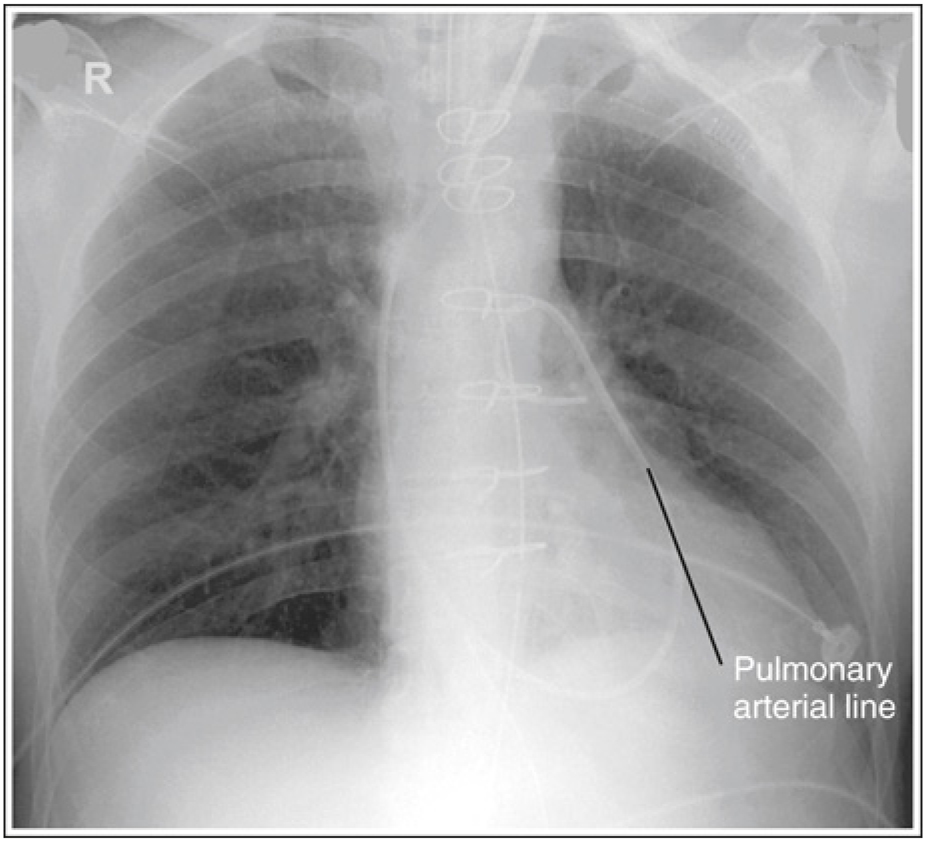


FIGURE 3.6 AP chest demonstrating poor pulmonary arterial line placement.

TABLE 3.2

Chest Devices, Tubes, Lines, and Catheters

Device, Tube, or Catheter	Desired Location	Brightness and Subject Contrast to Visualize
Tracheostomy (Fig. 3.7)	Distal tip is placed 1–2 inches superior to carina	Upper mediastinal region
ETT (Figs. 3.8 and 3.9)	Distal tip is placed 1–2 inches superior to carina when neck is in neutral position	Upper mediastinal region
Pleural drainage tube (chest tube) (Figs. 3.10 and 3.11)	Fluid drainage–located laterally within pleural space at level of the fifth or sixth intercostal spaceAir drainage—located anteriorly within pleural space at level of midclavicle	Radiopaque identification line and side hole interruption
CVC (Figs. 3.12 and 3.13)	Inserted into subclavian or jugular vein and extends to superior vena cava, about 2.5 cm above right atrial junction	CVC within heart shadow
Pulmonary arterial	Inserted into subclavian, internal or external jugular,	Catheter within heart shadow

Device, Tube, or Catheter	Desired Location	Brightness and Subject Contrast to Visualize
catheter (Fig. 3.14)	or femoral vein and advanced through right atrium into pulmonary artery	
UAC	Inserted into umbilicus and coursed to midthoracic aorta (T6–T9) or below level of renal arteries, at approximately L1–L2	UAC on lateral chest projection adjacent to vertebral bodies
UVC (Fig. 3.15)	Inserted into umbilicus and advanced to junction of right atrium and inferior vena cava	UVC from umbilicus to heart
Pacemaker (Figs. 3.16–3.18)	Internal pacemaker implanted in subcutaneous fat in anterior chest wall and catheter tip(s) directed to right atrium or right ventricle	Pacemaker in lateral thorax and catheter tip(s) within heart shadow
Automatic ICD (Fig. 3.19)	ICD is implanted in subcutaneous fat in anterior chest wall and	ICD in lateral thorax and catheter tip(s)

Device, Tube, or Catheter	Desired Location	Brightness and Subject Contrast to Visualize
	catheter tip(s) directed to right atrium or right ventricle	within heart shadow

CVC, Central venous catheter; *ETT*, endotracheal tube; *ICD*, implantable cardioverter defibrillator; *UAC*, umbilical artery catheter; *UVC*, umbilical vein catheter.

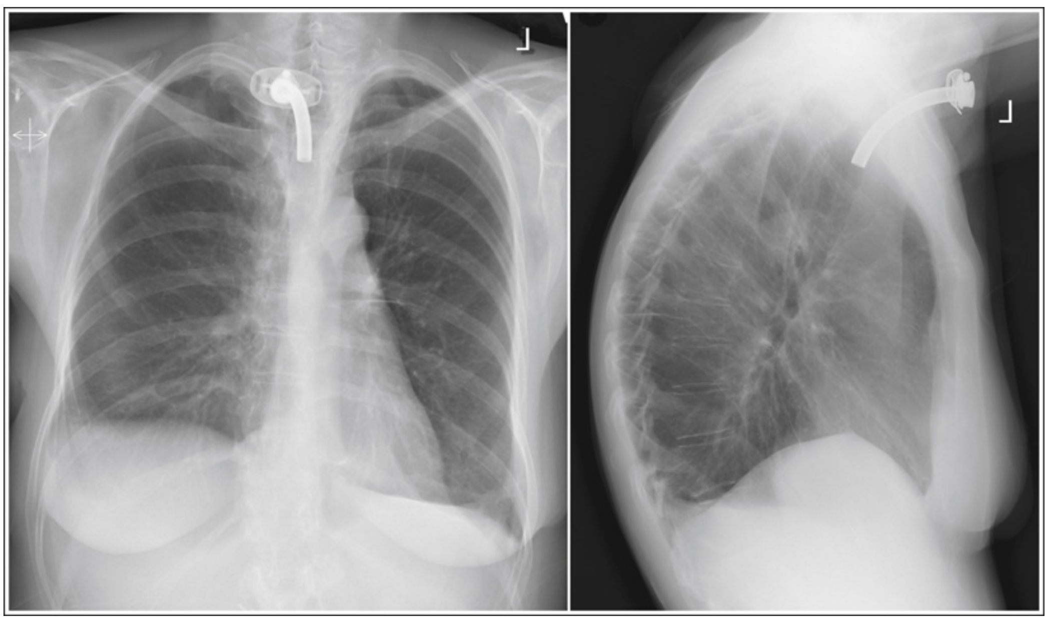


FIGURE 3.7 PA and lateral chest demonstrating tracheostomy placement.

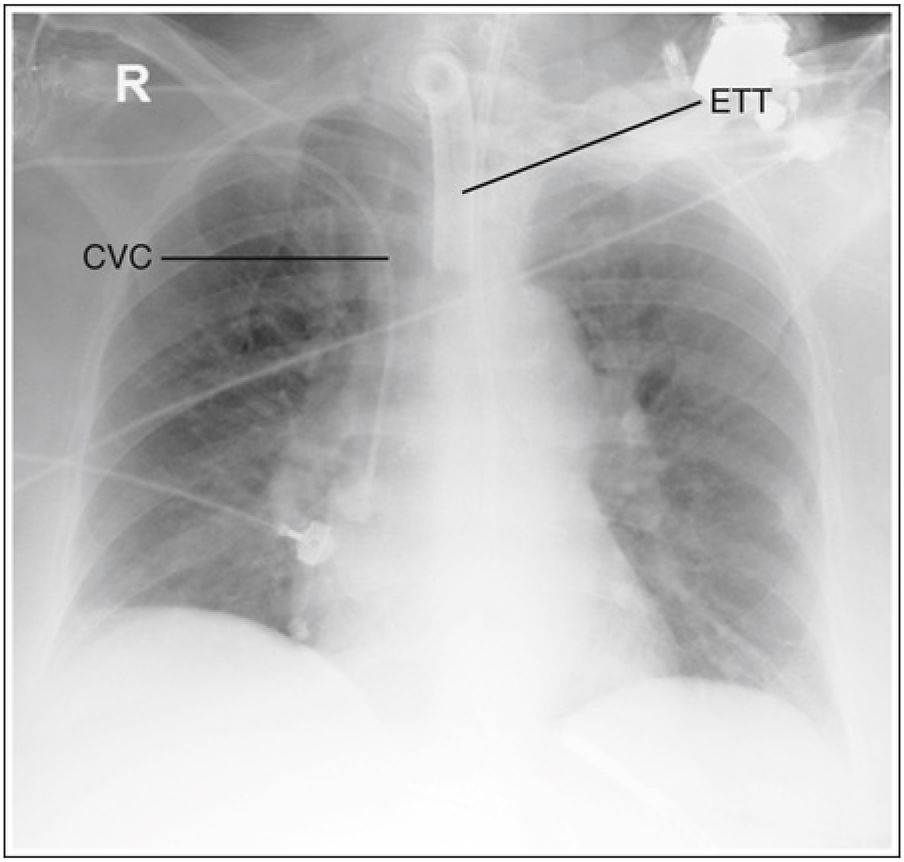


FIGURE 3.8 AP chest demonstrating accurate placement of an ETT and CVC.

Tracheostomy

The tracheotomy is a surgical procedure that creates an opening into the trachea to provide an airway. The distal tip of the tracheostomy tube should be positioned 1 to 2 inches (2.5 to 7 cm) from the tracheal bifurcation (carina). Projections are not taken for placement of the tube, but it should be noted that when the patient has a tracheostomy, special care needs to be taken when moving the patient so it does not come loose (**Fig. 3.7**).

Endotracheal Tube

The endotracheal tube (ETT) is a large, stiff plastic, thick-walled tube inserted through the nose or mouth into the trachea. It is used to manage the airway, for mechanical ventilation, and for suctioning. For adults, the distal tip of the ETT should be positioned 1 to 2 inches (2.5 to 7 cm) superior to the carina (**Fig. 3.8**).

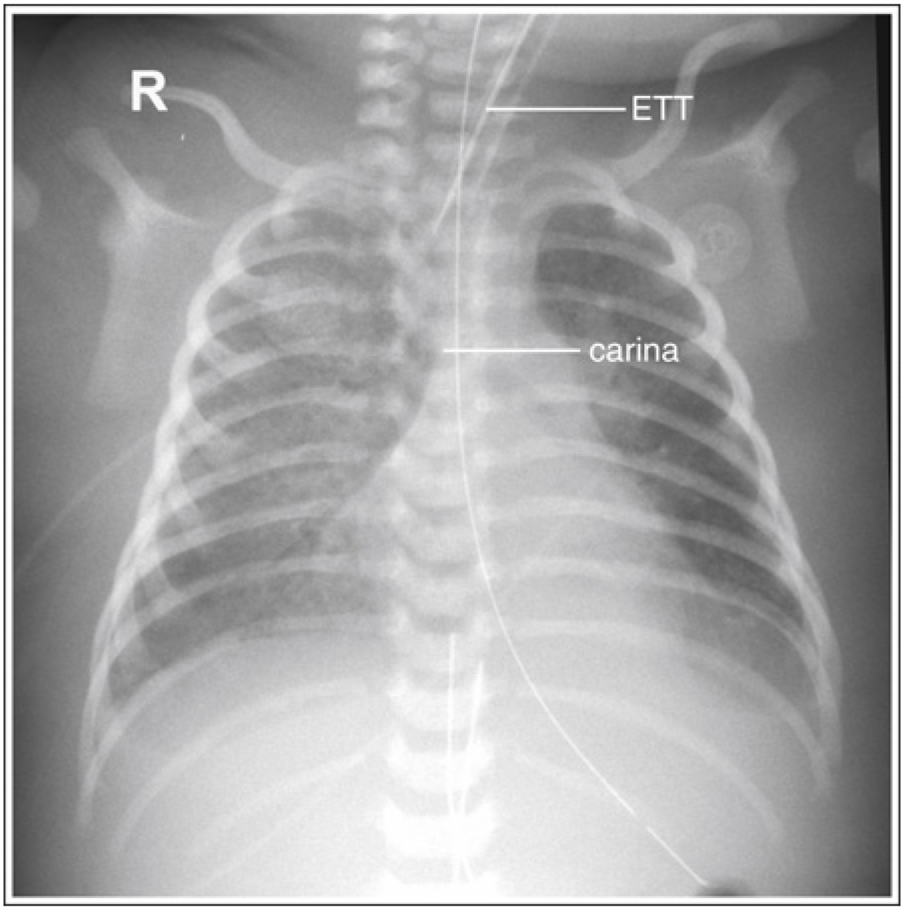


FIGURE 3.9 Neonate AP chest demonstrating accurate placement of an ETT.

For neonates, the distal tip of the ETT should reside between the thoracic inlet and carina, which is at the level of T4 on the neonate (**Fig. 3.9**). With the distance from the thoracic inlet to the carina being minimal on a neonate, the position of this tube is critical to within a few millimeters.

When imaging for ETT placement, the face needs to be facing forward and the cervical vertebrae should be in a neutral position. With head rotation and cervical vertebrae flexion and extension, the ETT tip can move superiorly and inferiorly about 2 cm, respectively, making it more uncertain whether the tube is positioned in the correct location. Too superior positioning of the tube may place it in the esophagus, and too inferior placement may place the tube in the right main bronchus, causing hyperinflation of the right lung and collapse of the left lung. Projections taken for ETT placement are to demonstrate penetration of the upper mediastinal region, and the longitudinal collimation should remain open to the bottom of the lip to include the upper airway.

Pleural Drainage Tube

The pleural drainage tube is a 1.25-cm diameter thick-walled tube used to remove fluid or air from the pleural space that could result in atelectasis (collapse of the lung). For drainage of air (e.g., pneumothorax), the tube is placed anteriorly within the pleural space at the level of the midclavicle (Figs. **3.10** and **3.11**). For drainage of fluid (e.g., hemothorax or pleural effusion), the tube is placed laterally within the pleural space at the level of the fifth or six intercostal space. The side hole of the tube is marked by an interruption of the radiopaque identification line. Projections taken for pleural drainage tube placement ideally will visualize the radiopaque identification line interruption at the side hole.

Central Venous Catheter

The central venous catheter (CVC) is a small (2- to 3-mm) radiopaque catheter used to allow infusion of substances that are too toxic for peripheral infusion, such as for chemotherapy, total parenteral nutrition, dialysis, or blood transfusions, and to measure central venous pressure. The

CVC is commonly inserted into the subclavian or jugular vein and extends to the superior vena cava, about 2.5 cm above the right atrial junction (Figs. **3.12** and **3.13**). Projections taken for CVC placement should visualize the CVC and any lung condition that might result if tissue perforation occurred during line insertion, such as pneumothorax or hemothorax.

Pulmonary Arterial Catheter (Swan-Ganz Catheter)

The pulmonary arterial catheter is similar to the CVC catheter but it is longer. It is used to measure atrial pressures, pulmonary artery pressure, and cardiac output. The measurements obtained are used to diagnose ventricular failure and monitor the effects of specific medication, exercise, and stress on heart function. The pulmonary arterial catheter is inserted into the subclavian, internal or external jugular, or femoral vein and is advanced through the right atrium into the pulmonary artery (**Fig. 3.14**). Projections taken for pulmonary arterial catheter placement should visualize the catheter and mediastinal structures to determine adequate placement.

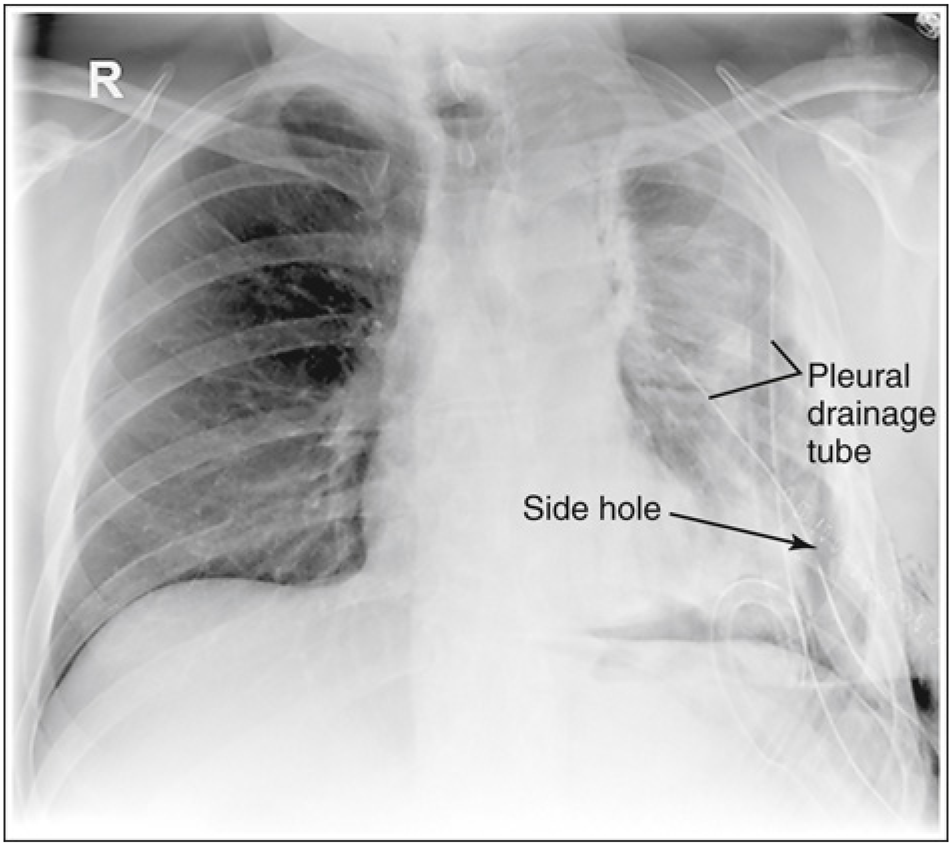


FIGURE 3.10 AP chest projection demonstrating accurate placement of two pleural drainage tubes.

Umbilical Artery Catheter

The umbilical artery catheter (UAC) is only seen in neonates because the cord has dried up and fallen off in older infants. The UAC is used to measure oxygen saturation. Optimal location for the UAC is in the midthoracic aorta (T6 to T9) or below the level of the renal arteries, at approximately L1 to L2. On a lateral chest projection, the UAC is seen to lie posteriorly adjacent to the vertebral bodies because it courses in the aorta.

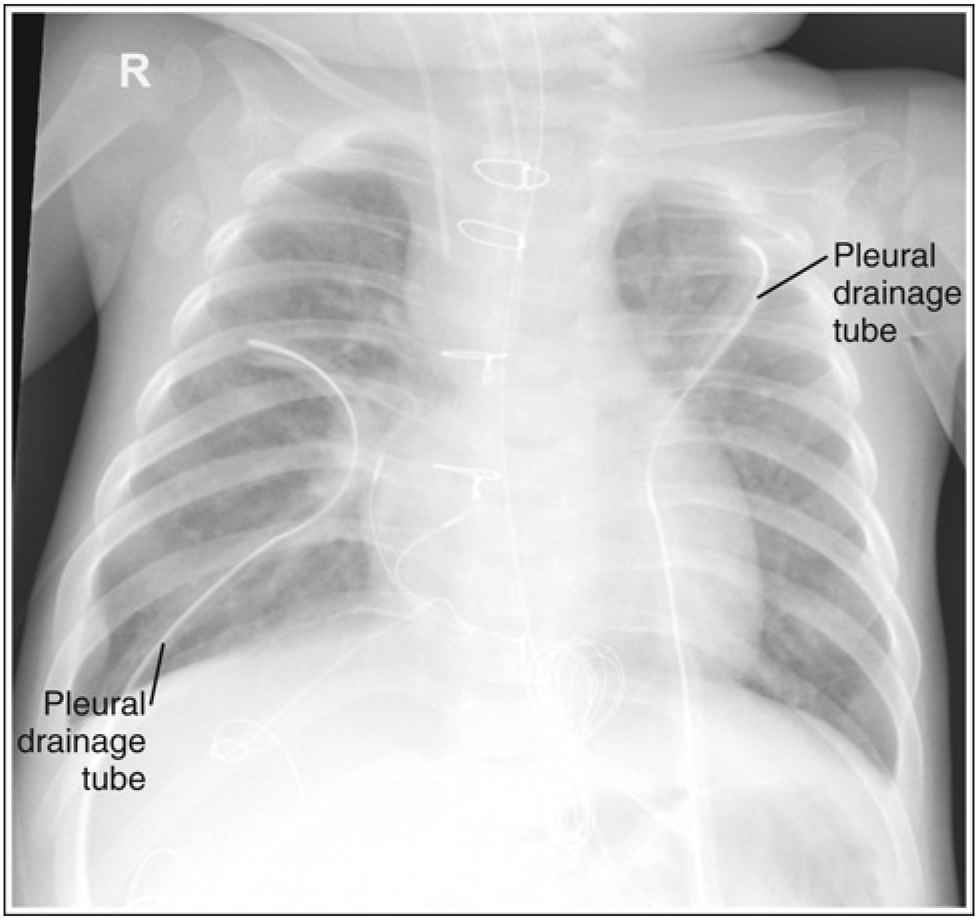


FIGURE 3.11 Infant AP chest demonstrating accurate placement of a pleural drainage tube in each lung.

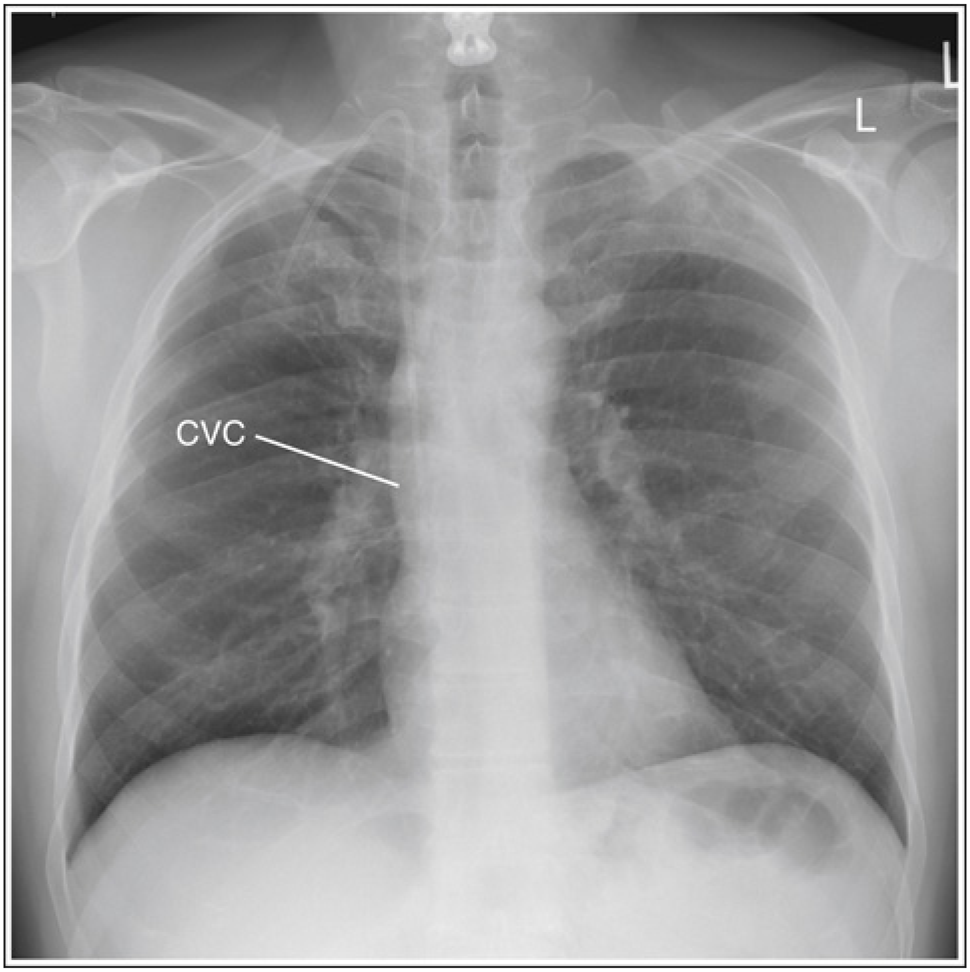


FIGURE 3.12 AP chest demonstrating accurate placement of a CVC.

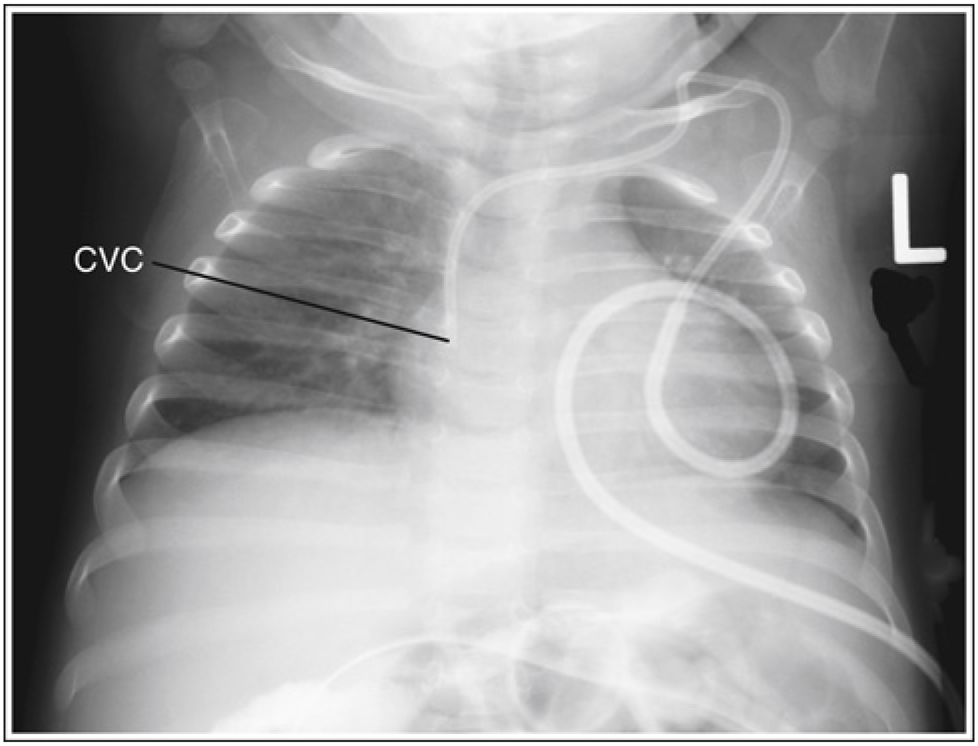


FIGURE 3.13 Neonate AP chest demonstrating accurate CVC placement.

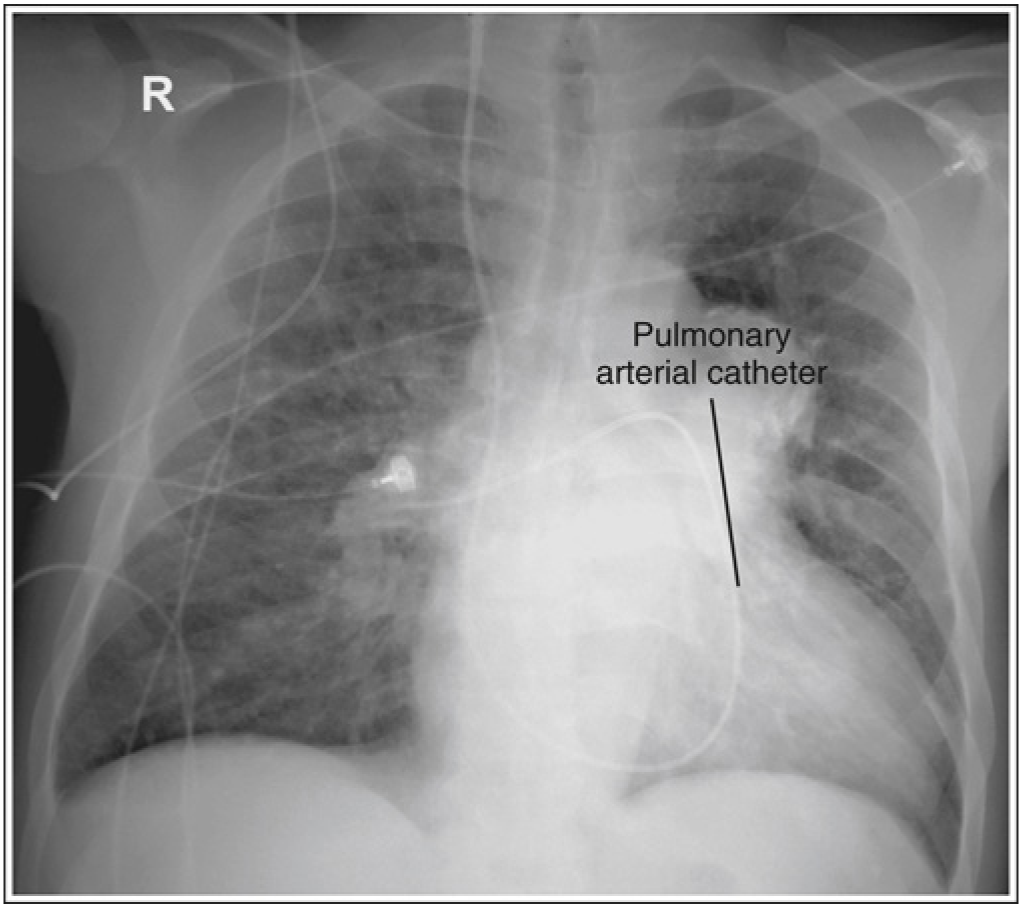


FIGURE 3.14 AP chest demonstrating accurate pulmonary arterial catheter placement.

Umbilical Vein Catheter

The umbilical vein catheter (UVC) is only seen in neonates, because the cord has dried up and fallen off in older infants. The UVC is used to deliver fluids and medications. The UVC courses anteriorly and superiorly to the level of the heart. The ideal location of the UVC is at the junction of the right atrium and inferior vena cava (**Fig. 3.15**).

Pacemaker

The pacemaker is used to regulate the heart rate by supplying electrical stimulation to the heart. This electrical signal will stimulate the heart the

needed amount to maintain an effective rate and rhythm. The internal pacemaker is surgically implanted in the subcutaneous fat in the anterior chest wall below the clavicle and the catheter tip(s) directed to the right atrium or the right ventricle. On a PA or AP chest projection, the pacemaker is typically seen laterally and the catheter tip(s) is seen in the heart shadow (**Fig. 3.16**). Projections taken for pacemaker placement should visualize the catheter tips through the mediastinal structures.

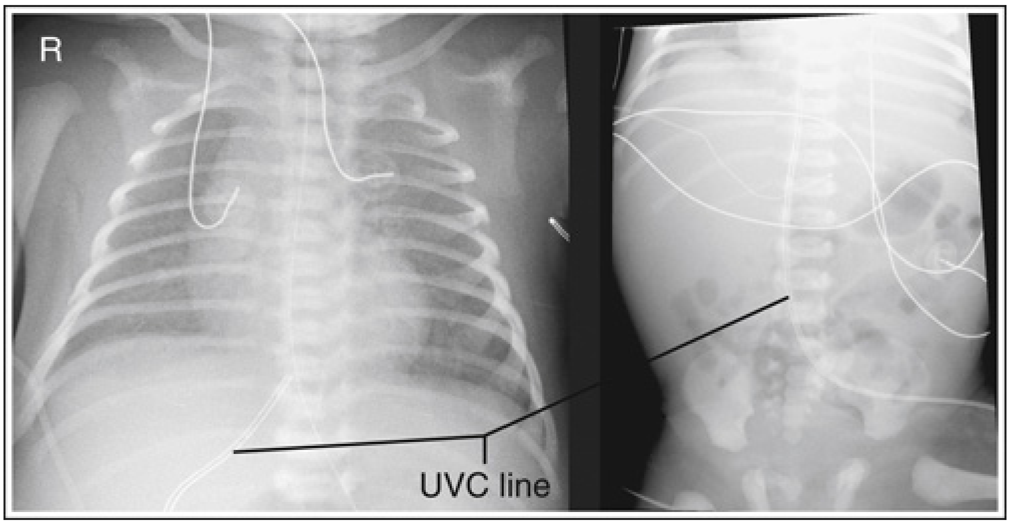


FIGURE 3.15 Neonate AP chest and abdomen demonstrating accurate placement of an umbilical vein catheter *(UVC)*.

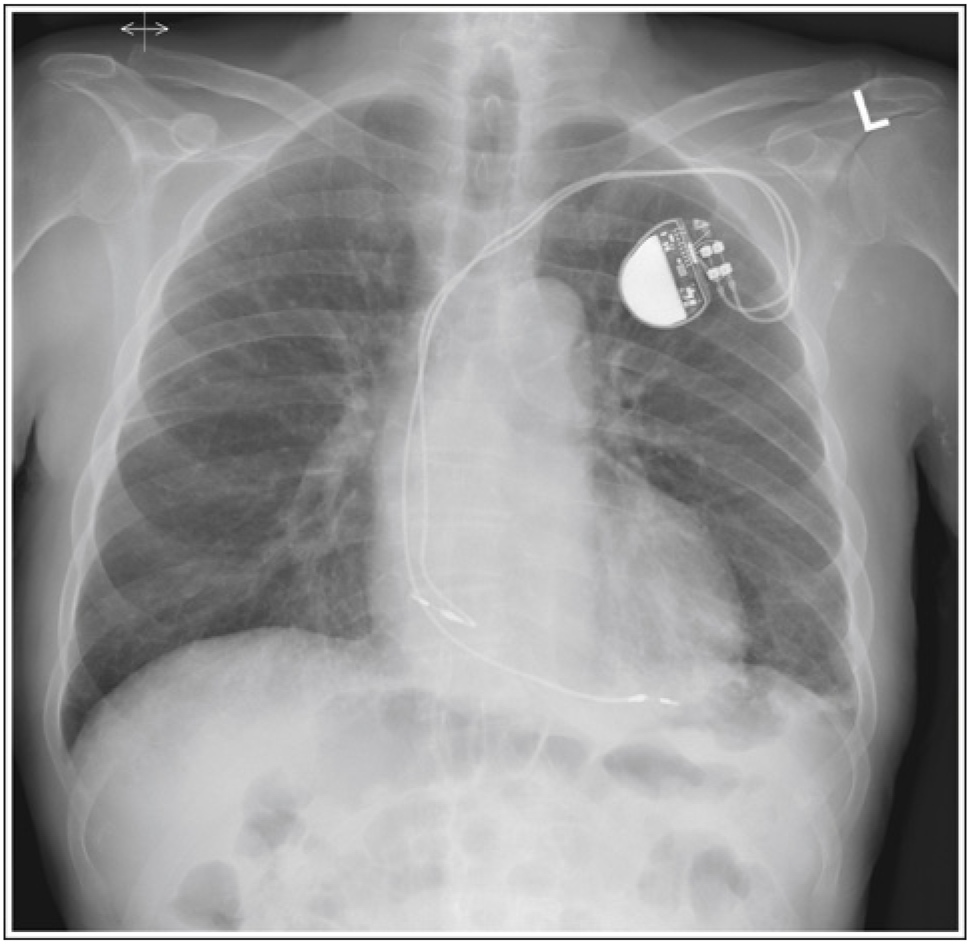


FIGURE 3.16 AP chest demonstrating accurate pacemaker placement, with optimal heart penetration.

Compare the difference in heart penetration and catheter tips visualization between the PA chests in Figs. **3.16** and **3.17**. **Fig. 3.16** is optimal.

Because the pacemaker is inserted in the upper thorax, care should be taken when lifting the arm of a patient whose pacemaker was inserted within 24 hours of the examination, because elevation may dislodge the pacemaker and catheter (**Fig. 3.18**).

Automatic Implantable Cardioverter Defibrillator

The implantable cardioverter defibrillator (ICD) is implanted in the anterior chest wall, as with the pacemaker, and the catheter tip(s) directed to the right atrium or the right ventricle. It is used to detect heart arrhythmias and then deliver an electrical shock to the heart to convert it to a normal rhythm. On a PA or AP chest projection, the ICD is typically seen laterally and the catheter tip(s) is seen in the heart shadow (**Fig. 3.19**).

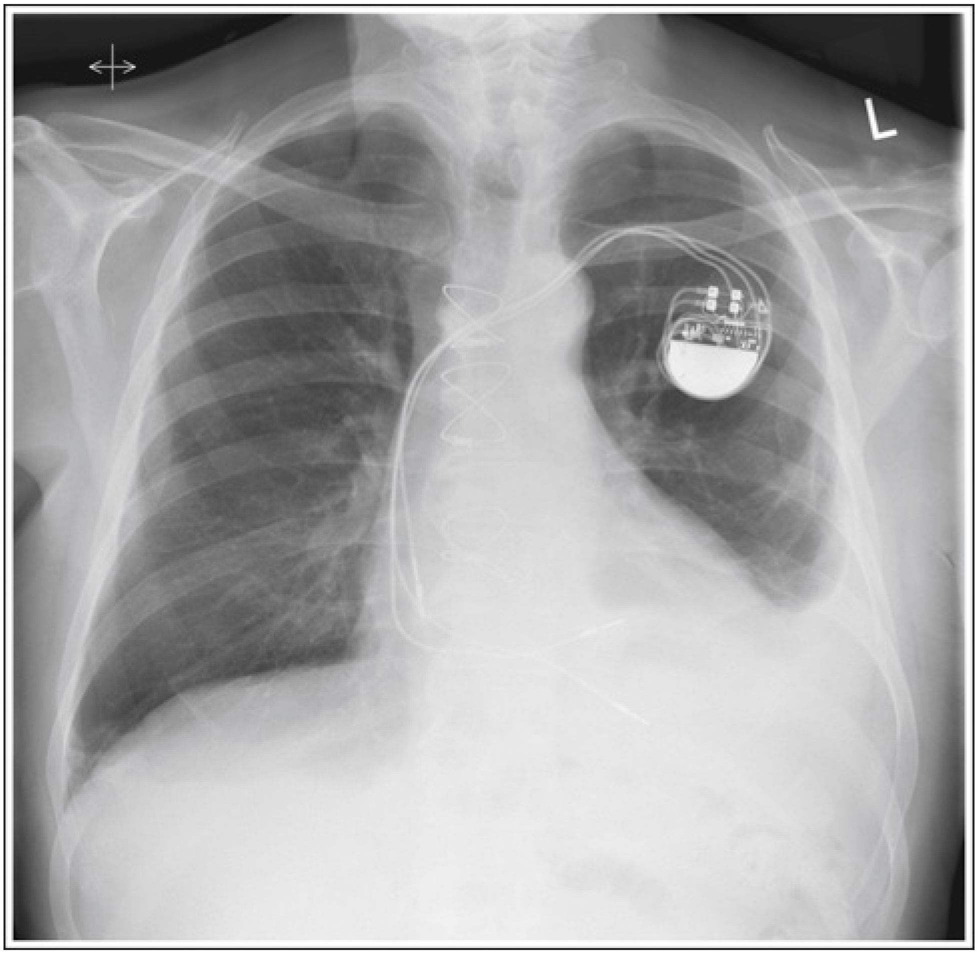


FIGURE 3.17 AP chest demonstrating accurate pacemaker placement, with poor heart penetration.

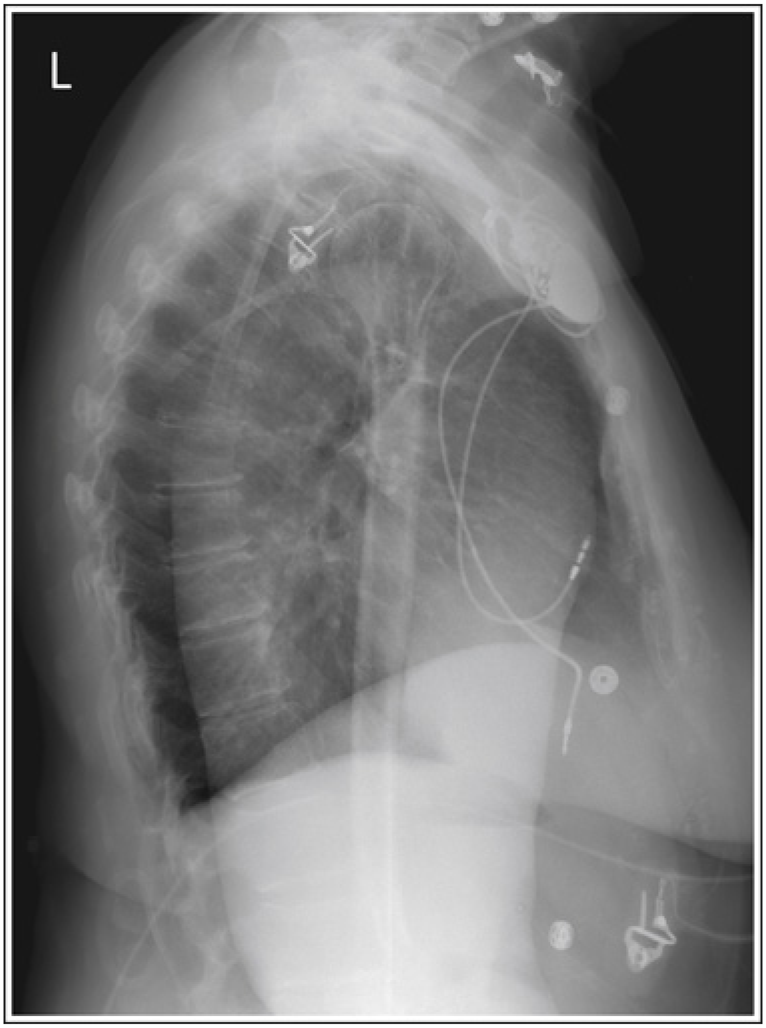


FIGURE 3.18 Lateral chest demonstrating accurate pacemaker placement and arm in chest position when the exam is obtained within 24 hours of pacemaker placement.

External Monitoring Tubes and Lines

All external monitoring tubes or lines that can be removed or shifted out of the lung field should be. This includes oxygen tubing, electrocardiographic leads, external portions of nasogastric tubes, enteral feeding tubes, temporary pacemakers, and telemetry devices. Leaving these tubes and

lines overlying the lung field may result in obscuring important lung details (**Fig. 3.20**).

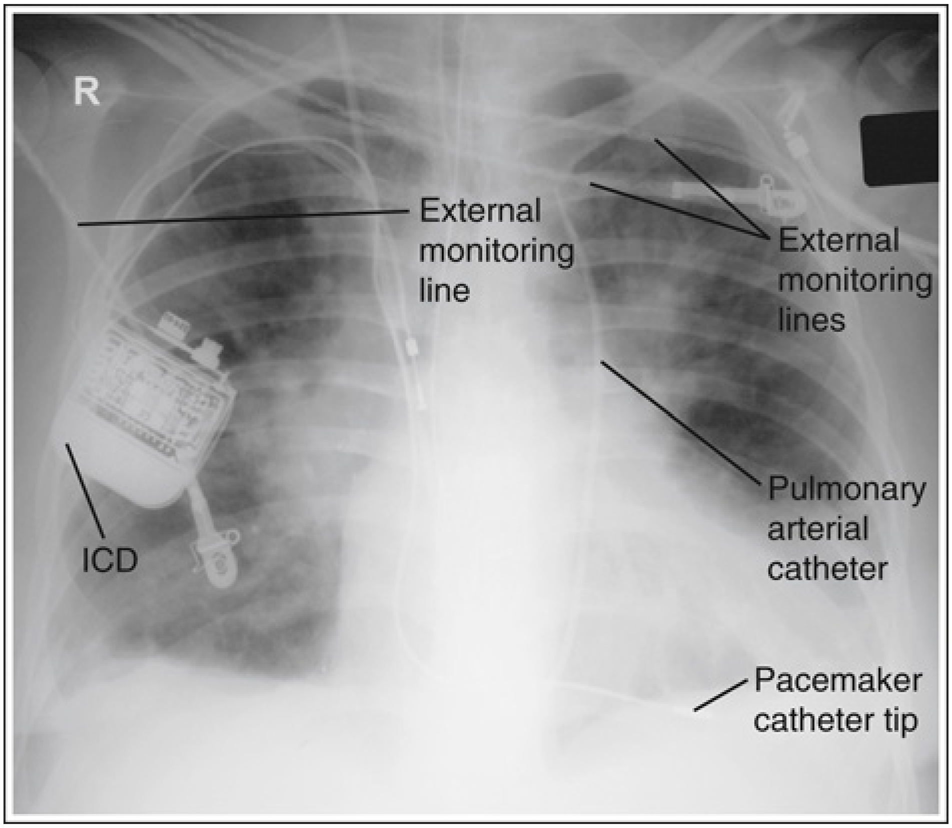


FIGURE 3.19 AP chest demonstrating accurate placement of ICD and pulmonary arterial catheter.

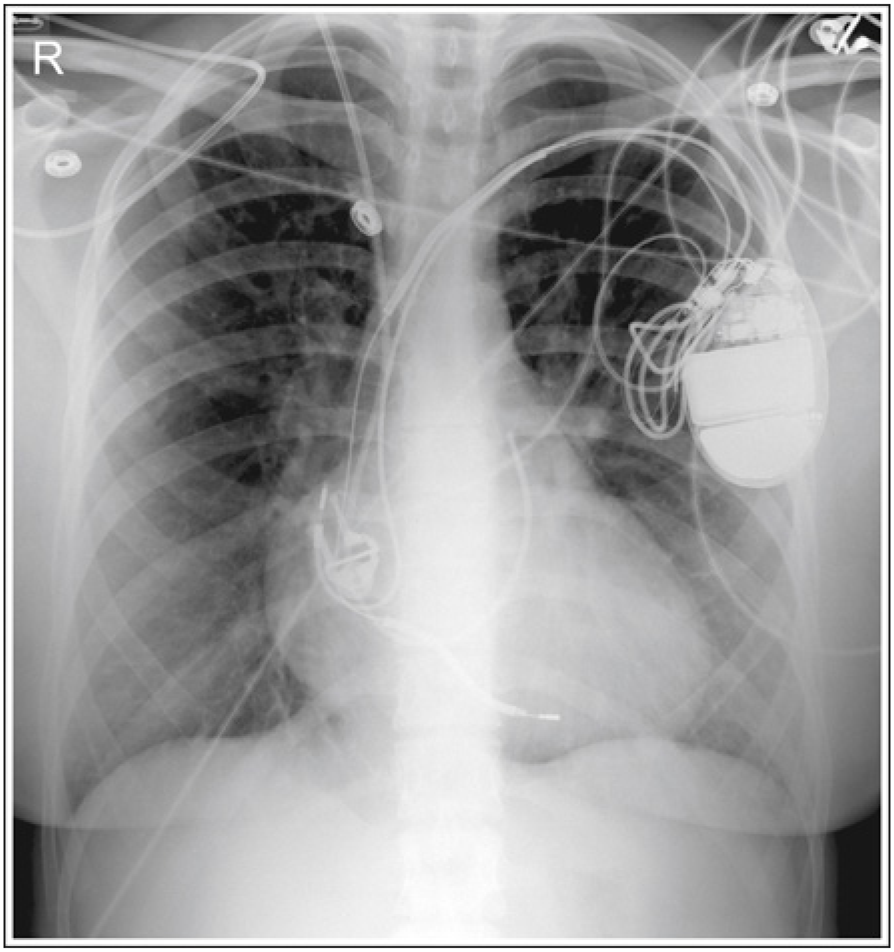


FIGURE 3.20 AP chest demonstrating removable external monitoring lines obscuring lung details.

Chest: PA Projection

See **Table 3.3** and Figs. **3.21** and **3.22**.

Large Pendulous Breasts

Large pendulous breasts may obscure the lung bases, as they add a dense thickness to this region of the lungs (**Fig. 3.23**). This density is reduced by elevating and separating the breasts before resting the patient against the upright image receptor (IR).

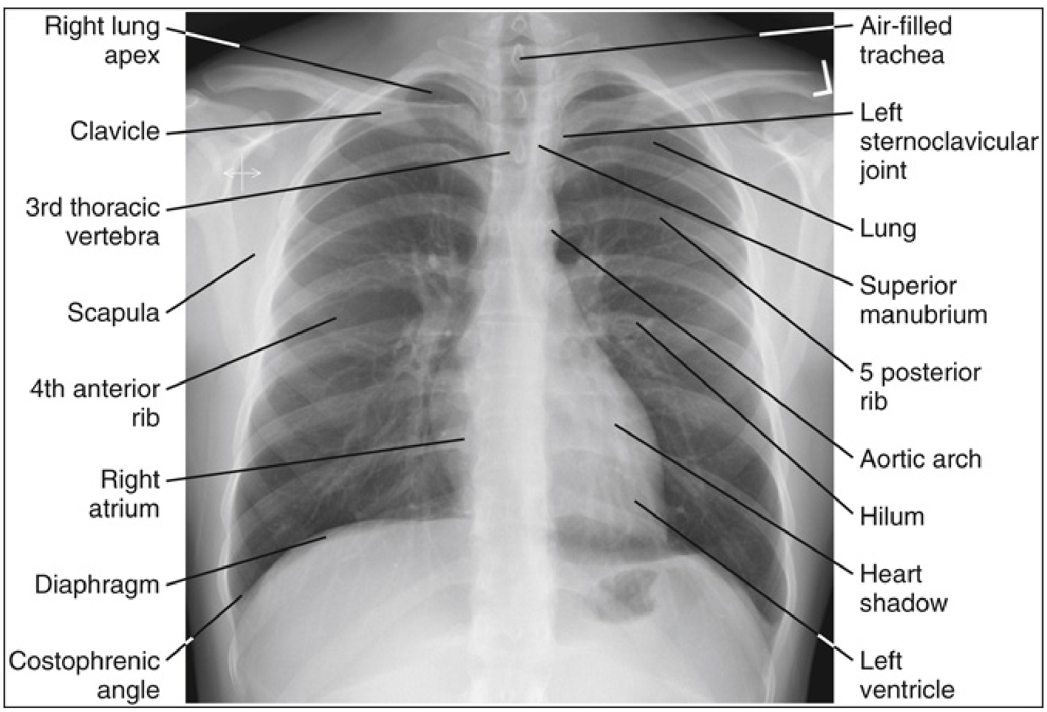


FIGURE 3.21 PA chest with accurate positioning.

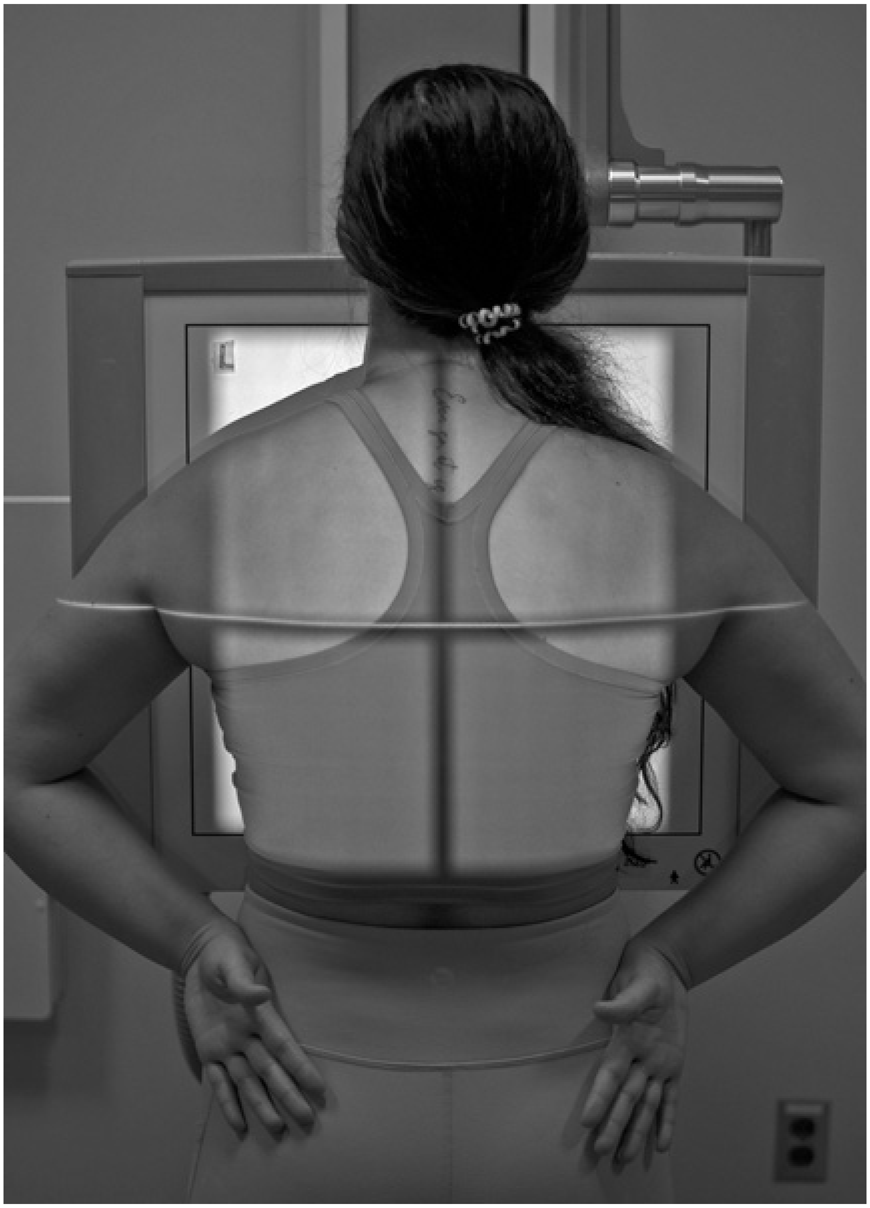


FIGURE 3.22 Proper patient positioning for PA chest projection.

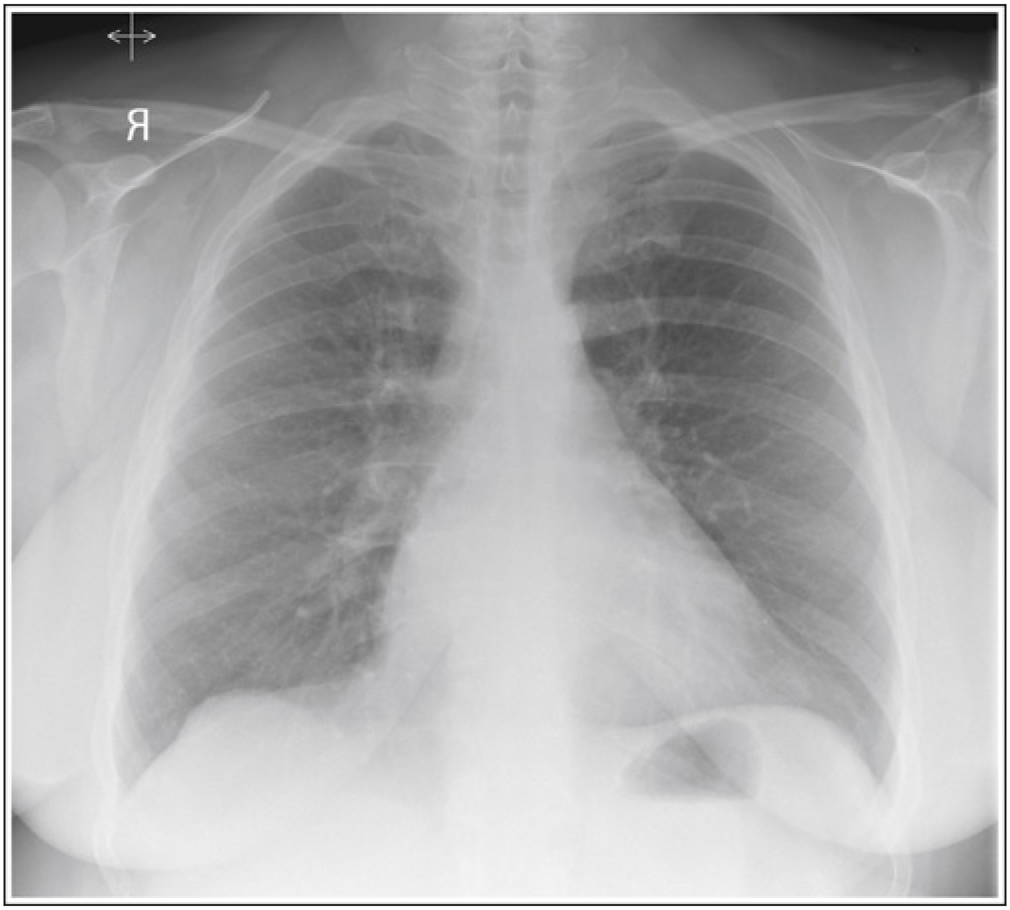


FIGURE 3.23 PA chest on patient with large pendulous breasts.

TABLE 3.3

Nipple Shadows

The nipples on male and female patients can appear to be soft tissue masses. When in question, the projection is repeated after attaching small lead markers on the nipples. These markers will identify the nipples from the overlapping lung tissue.

Singular Mastectomy

Special attention should be given to female patients who have had one breast removed. The side of the patient on which the breast was removed may need to be placed at a greater OID than the opposite side to prevent rotation (**Fig. 3.24**).

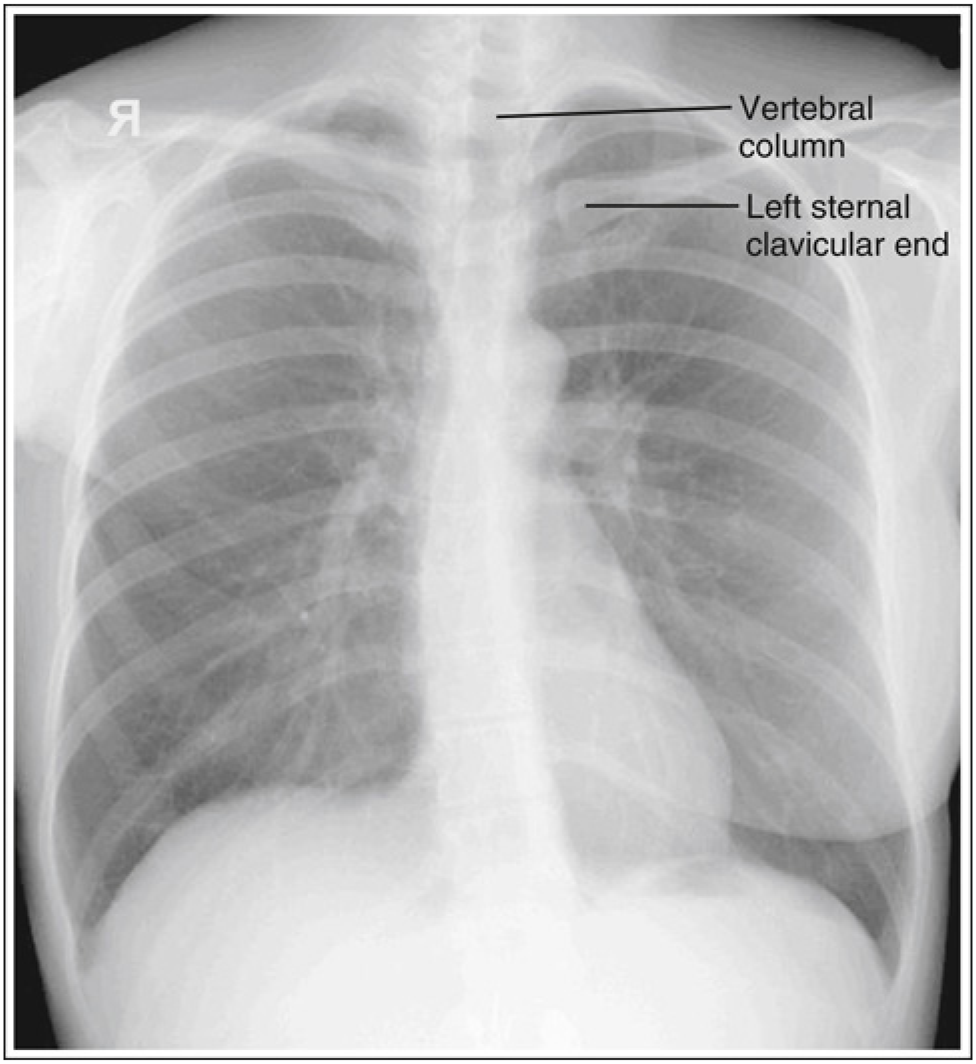


FIGURE 3.24 PA chest on patient with right-sided mastectomy, with right side of chest rotated closer to IR than left side.

Augmentation Mammoplasty

Augmentation mammoplasty (breast implants) is a surgical procedure to enhance the size and shape of a woman's breast. Women get breast implants for reconstructive purposes or cosmetic reasons. They are medical devices with a solid silicone, rubber shell that is filled with either saline solution or elastic silicone gel. Breast implants vary by filler, size, shape, diameter, and position on the chest, and they are inserted directly under the breast tissue or beneath the chest wall muscle. On chest projections, the breast implant may obscure the lung region that they are over, as they add a dense thickness to this region of the lungs (**Fig. 3.25**).

Body Habitus and IR Placement

There are four types of body habitus to consider when determining the direction, crosswise (CW) or lengthwise (LW), that the IR cassette is positioned for computed radiography systems, and when determining the appropriate field size for direct-capture (DR) systems: hypersthenic, sthenic, hyposthenic, and asthenic. The centering of the CR is also adjusted based on body habitus to increase or decrease collimation appropriately.

- A hypersthenic patient has a wide, short thorax, with a high diaphragm (**Fig. 3.26**). This body habitus requires the 17-inch (43-cm) field size to be placed CW and the 14-inch (35 cm) field size to be placed LW for the PA chest projections to include the entire lung field.

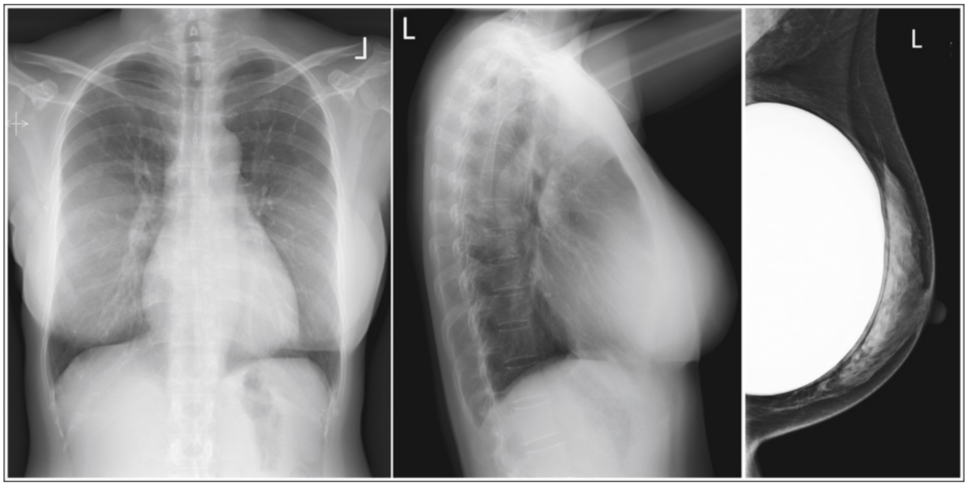


FIGURE 3.25 PA and lateral chest, and mammogram on same patient after augmentation mammoplasty.

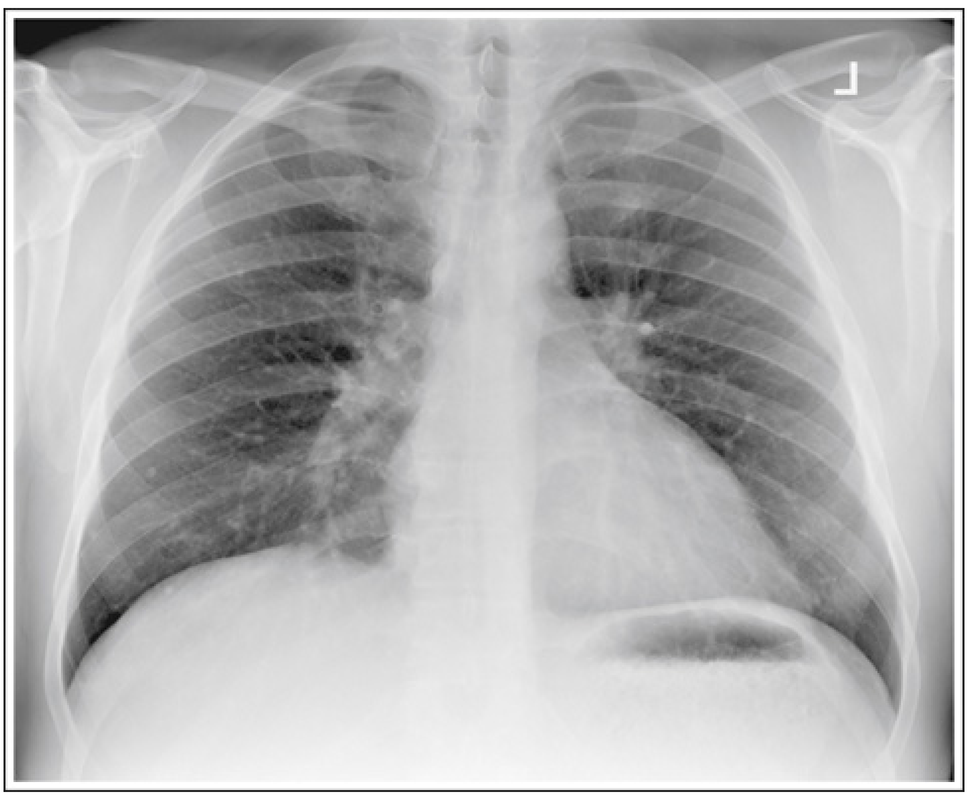


FIGURE 3.26 PA chest of hypersthenic patient.

- An asthenic patient has a long, narrow thoracic cavity, with a low diaphragm (**Fig. 3.27**).
- Sthenic and hyposthenic patients have thoracic cavities with lengths and widths that are between those of the hypersthenic and asthenic body habitus (Figs. **3.28** and **3.29**). The sthenic, hyposthenic, and asthenic types of body habitus require the 17-inch (43 cm) field size to be placed LW and the 14-inch (35 cm) field size to be CW for the PA chest projections to include the entire lung field.

Chest Rotation

A rotated chest demonstrates distorted mediastinal structures and creates an uneven brightness between the lateral borders of the chest. This brightness difference occurs because the x-ray beam traveled through less tissue on the chest side positioned away from the IR than on the side positioned closer to the IR. It may be detected when the chest has been rotated as little as 2 or 3 degrees. Because any variation in structural relationships or image brightness may represent a pathologic condition, the importance of providing nonrotated PA chest projections cannot be overemphasized. Rotation is readily detected on a PA chest by evaluating the distances between the vertebral column and the sternal ends of the clavicles, and by comparing the lengths of the posterior ribs. On a nonrotated PA chest, these distances and lengths are equal, respectively. On a rotated PA chest, the sternal clavicular end that demonstrates the least vertebral column superimposition and the side of the chest with the greatest posterior rib length represents the side of the chest positioned farthest from the IR (Figs. **3.24** and **3.30**).

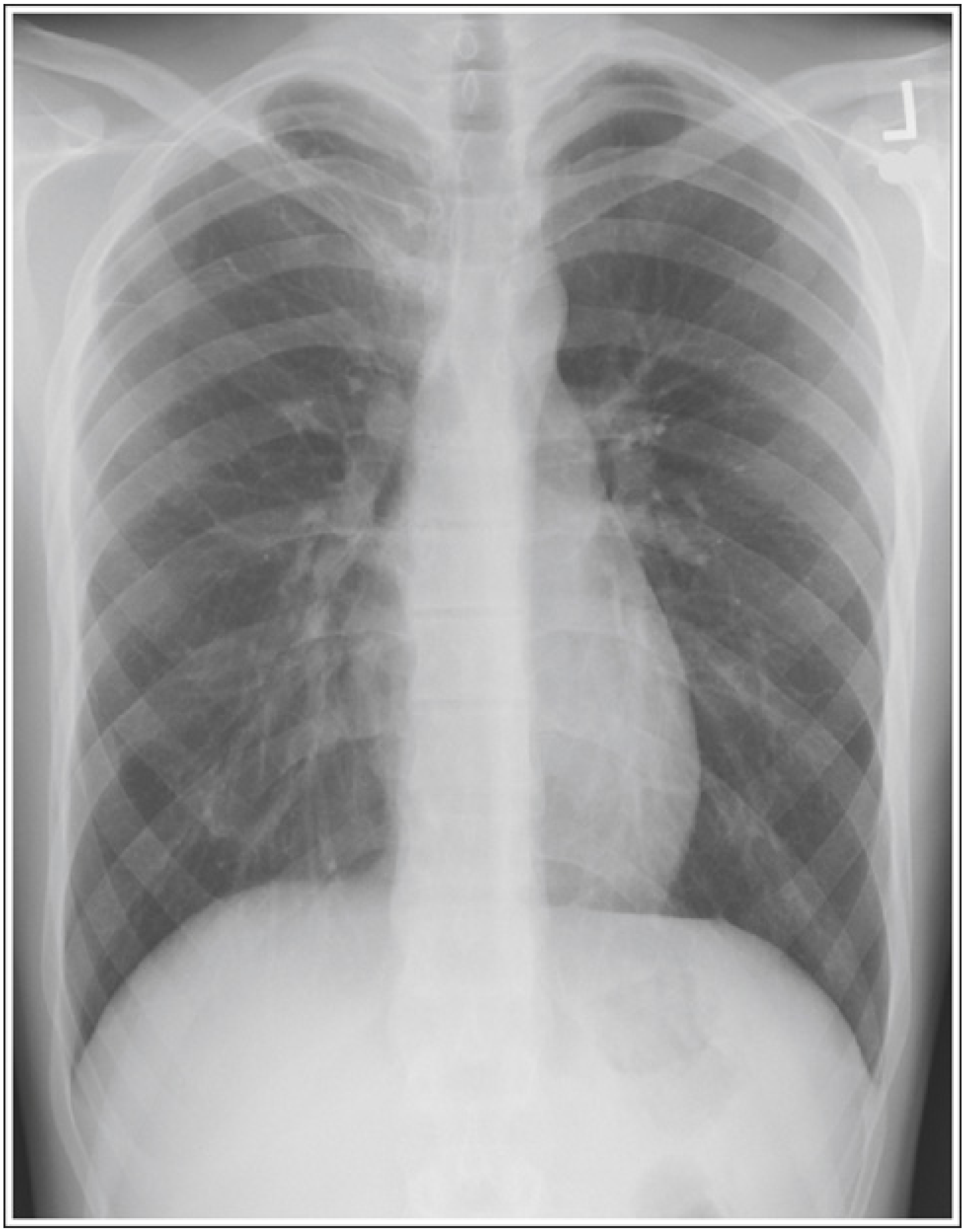


FIGURE 3.27 PA chest of asthenic patient.

AP Oblique Chest Projections

Occasionally an oblique chest projection is requested to better demonstrate an area. When this is requested a PA versus an AP oblique projection is routinely performed because it positions the heart and lung of interest closer to the IR. The LPO position demonstrates the left lung and the RPO

position demonstrates the right lung. The degree of rotation needed is department and reviewer determined. It may range from 10 to 60 degrees (**Fig. 3.31**). The resulting image will demonstrate chest rotation as described in the previous discussion.

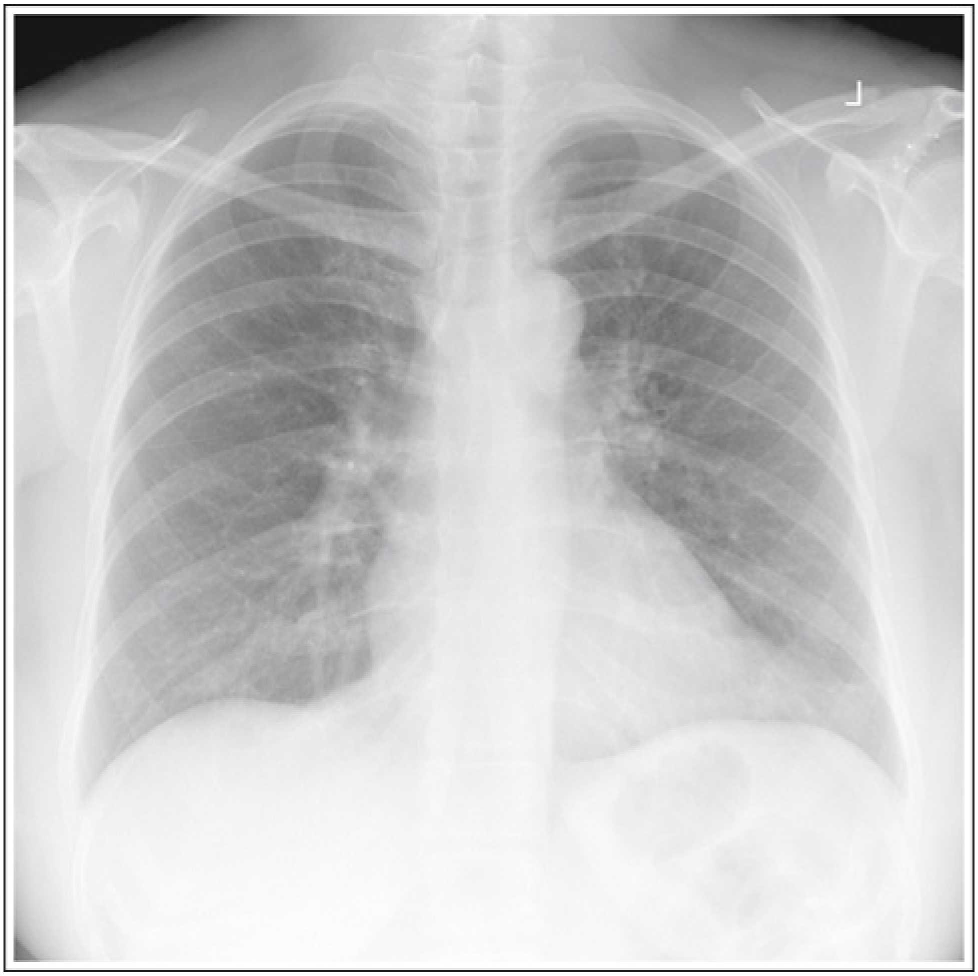


FIGURE 3.28 PA chest of sthenic patient.

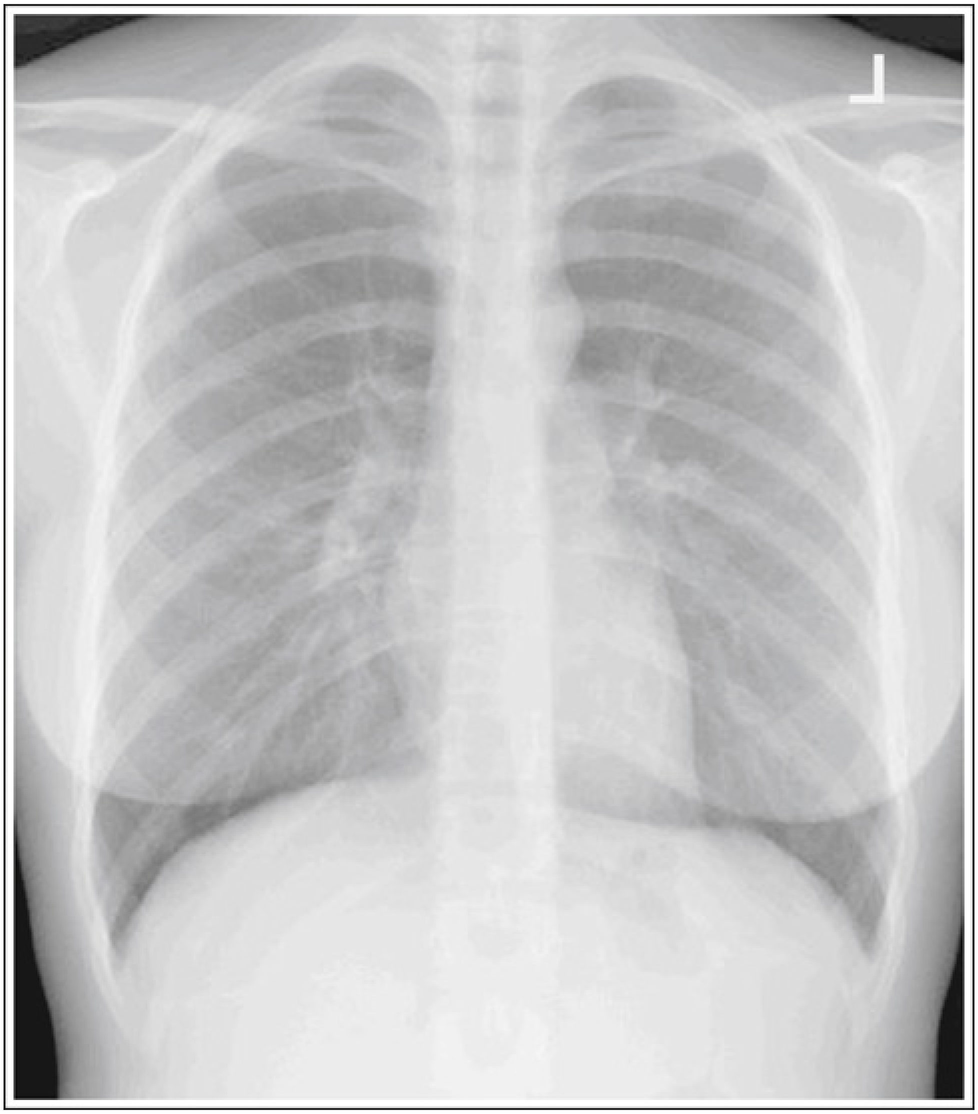


FIGURE 3.29 PA chest of hyposthenic patient.

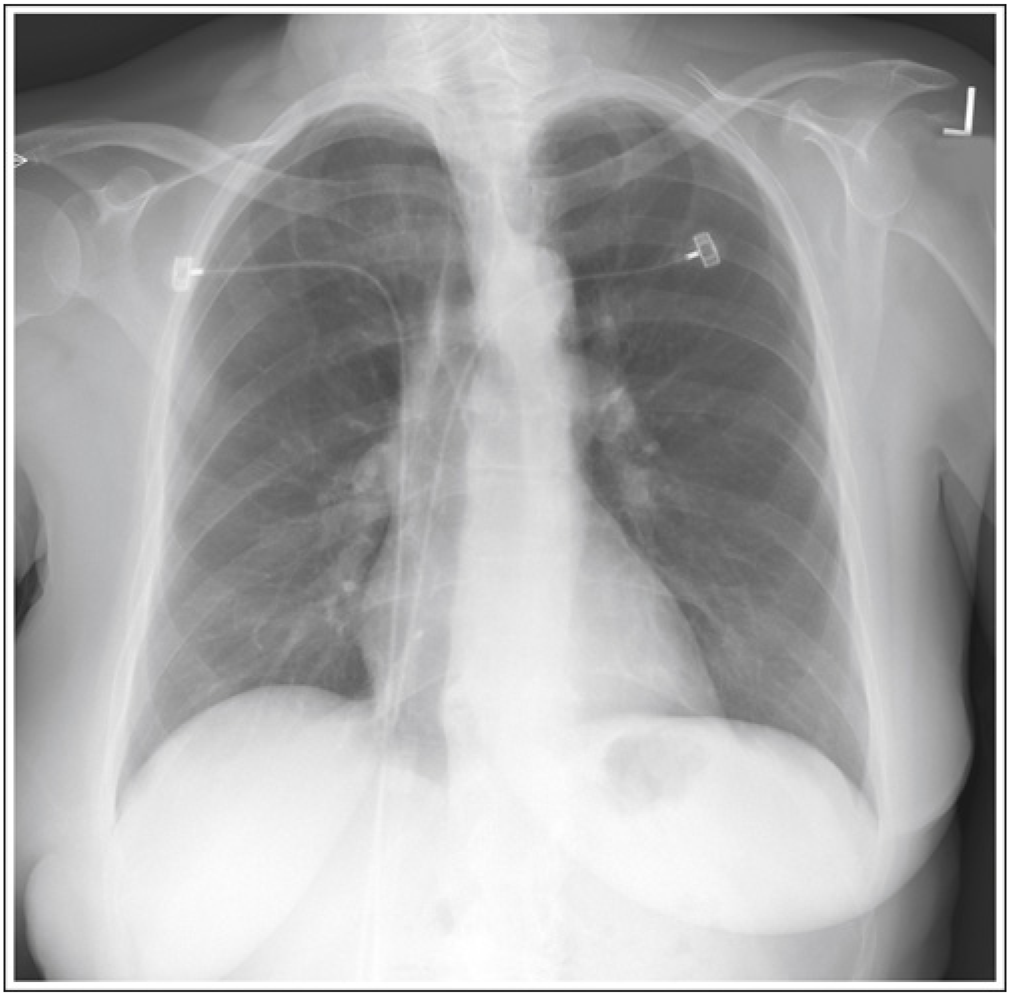


FIGURE 3.30 PA chest taken with left side of chest rotated closer to IR than right side.

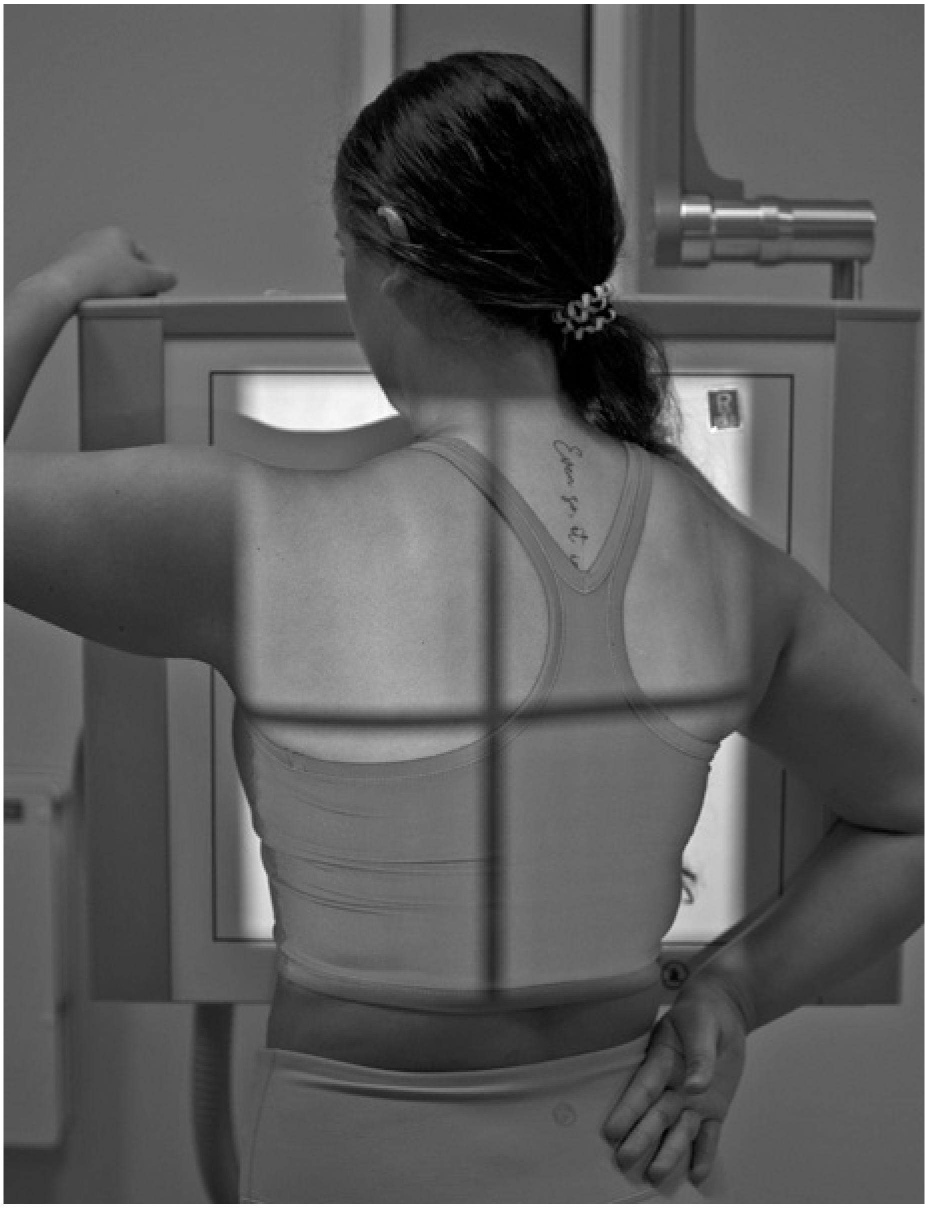


FIGURE 3.31 Proper patient positioning for 45-degree PA oblique (RAO) chest projection.

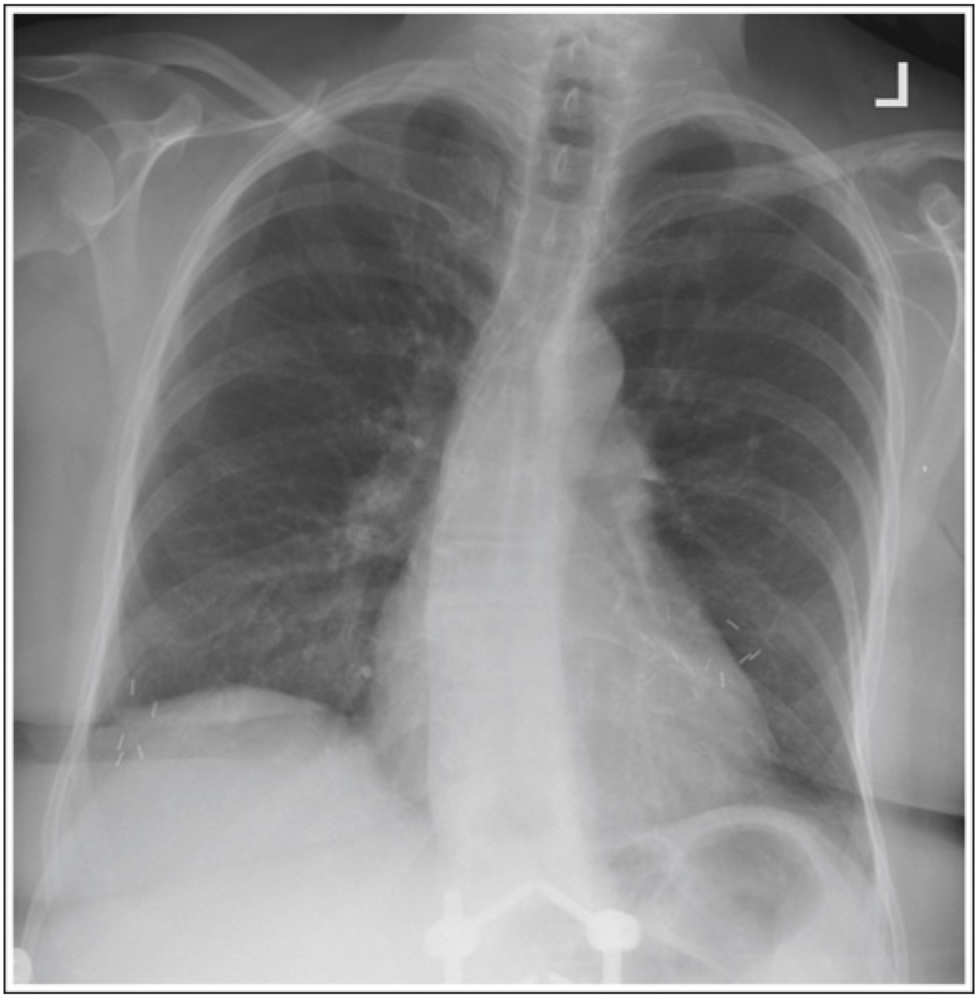


FIGURE 3.32 PA chest on patient with scoliosis.

Distinguishing Scoliosis From Rotation

Scoliosis is a condition of the spine that results in the vertebral column curving laterally instead of remaining straight. Scoliosis can be distinguished from rotation by comparing the distance from the vertebral column to the lateral lung edges down the length of the lungs. On projections of a rotated patient, the distances are uniform down the length of the lung field, although when both lungs are compared, the distance is shorter on one side. If the patient has scoliosis, the vertebral column to lateral lung edge distances vary down the length of each lung and between

each lung (**Fig. 3.32**). The amount of distance variation increases with the severity of the scoliosis.

Clavicles

The lateral ends of the clavicles are positioned on the same horizontal plane as the medial clavicle ends by depressing the shoulders. Accurate clavicle positioning lowers the lateral clavicles, positioning the middle and lateral clavicles away from the apical chest region and providing better visualization of the apical lung field. When a PA chest projection is taken without depression of the shoulders, the lateral ends of the clavicles are elevated, causing the middle and lateral clavicles to be demonstrated within the apical chest region (**Fig. 3.33**).

Scapulae

When the scapulae are accurately positioned outside the lung field by rolling the elbows and shoulders anteriorly, the superolateral portions of the lungs are seen without scapular superimposition. If a chest projection is taken without one or both of the shoulders adequately protracted, the scapula obtained with insufficient shoulder protraction will demonstrate the superolateral lung field superimposed by the scapula (**Fig. 3.34**). Scapular densities may prevent detection of abnormalities in the periphery of the lungs.

Many dedicated chest units provide holding bars for the arms. When using these holding bars, make certain that the shoulders are fully protracted. If the patient is unable to protract the shoulders while using the bars, position the arms as described in **Table 3.3**.

Anterior Midcoronal Plane Tilting

If the superior midcoronal plane is tilted anteriorly, as demonstrated in **Fig. 3.35**, the lungs and heart are foreshortened, the manubrium is situated at the level of the fifth thoracic vertebra or lower, and more than 1 inch (2.5 cm) of the apices is demonstrated above the clavicles (**Fig. 3.36**). This positioning error often occurs during imaging of women with pendulous breasts (see **Fig. 3.23**) and patients with protruding abdomens.

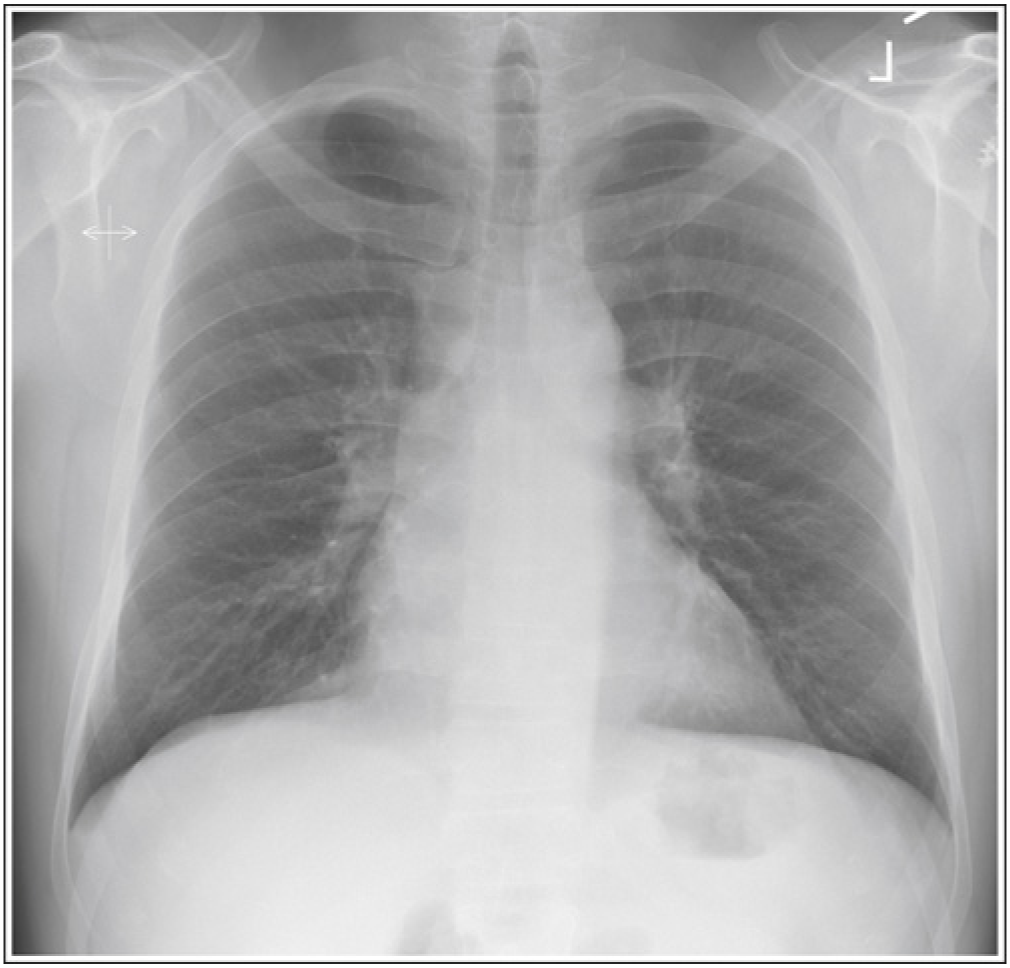


FIGURE 3.33 PA chest taken with elevated shoulders.

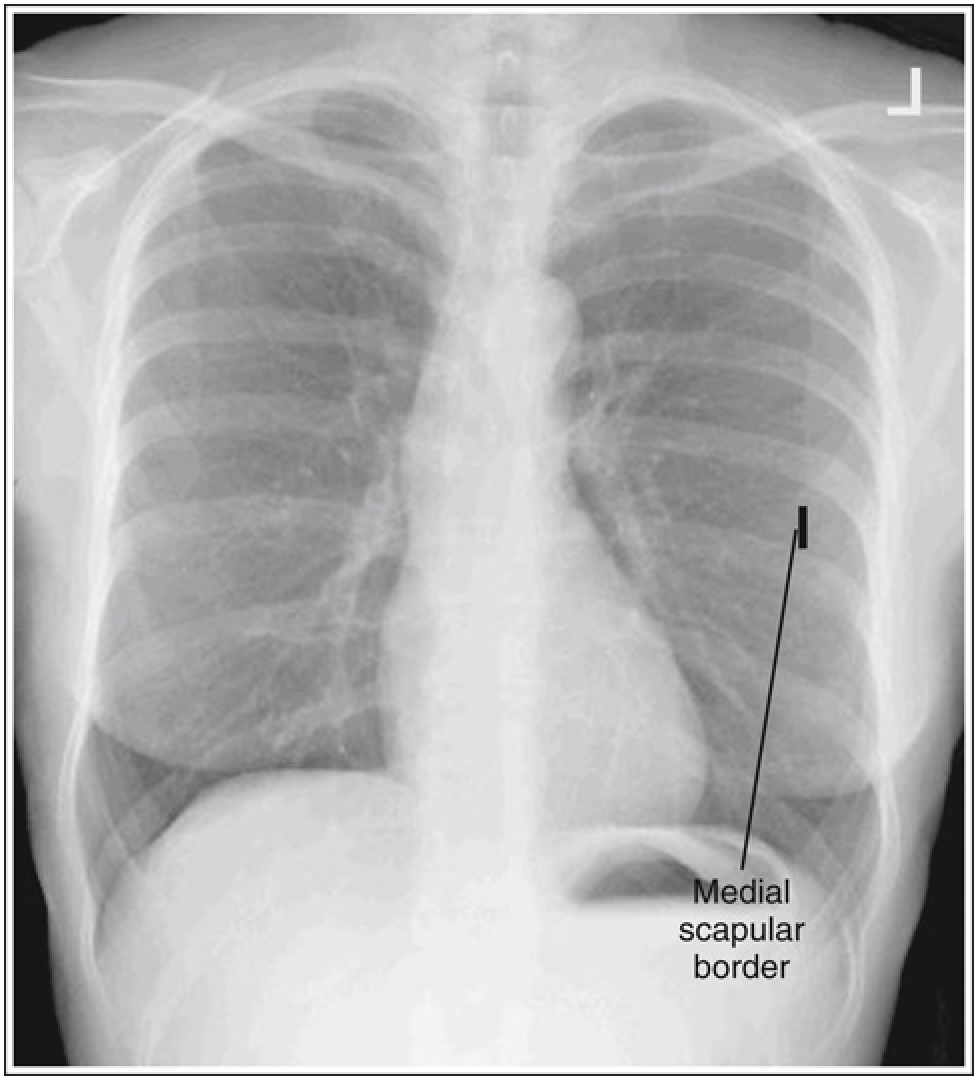


FIGURE 3.34 PA chest taken without shoulder protraction.

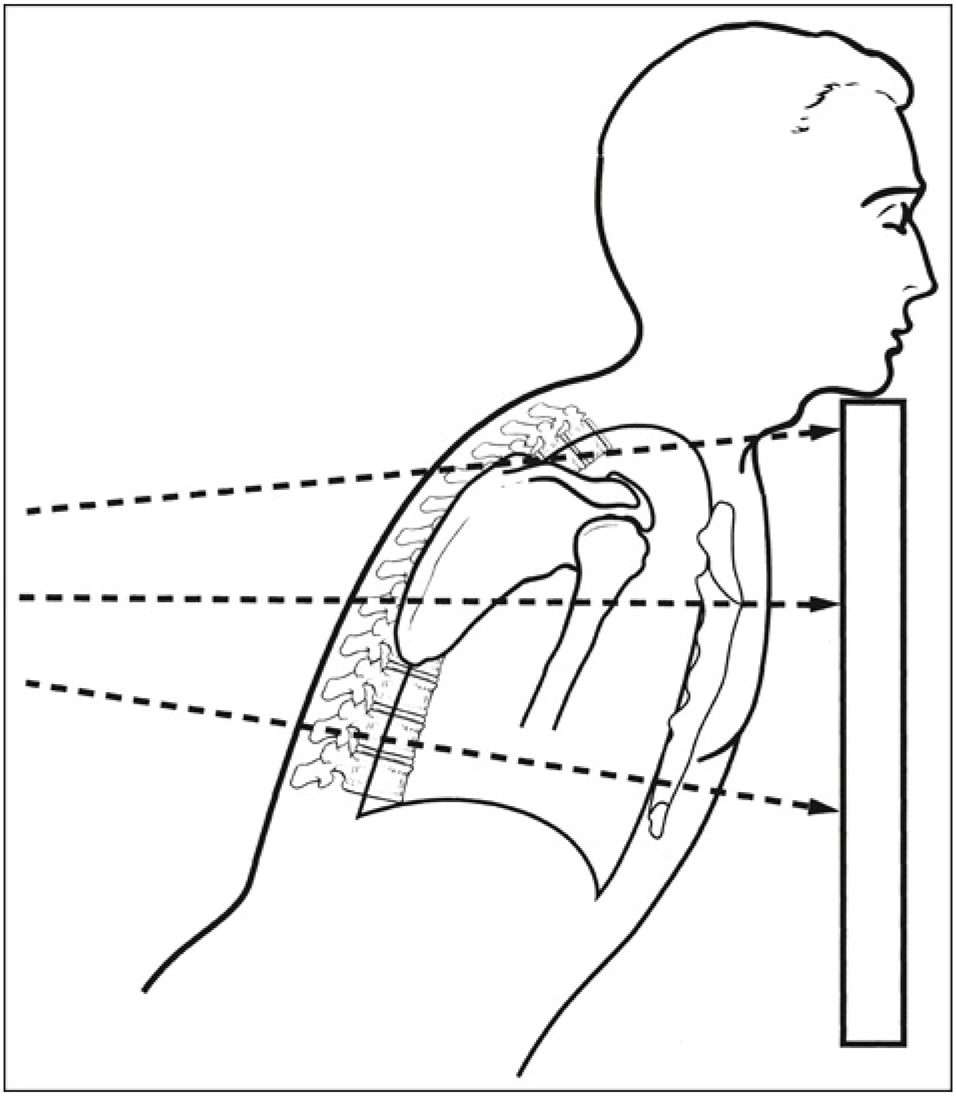


FIGURE 3.35 Superior midcoronal plane tilted anteriorly.

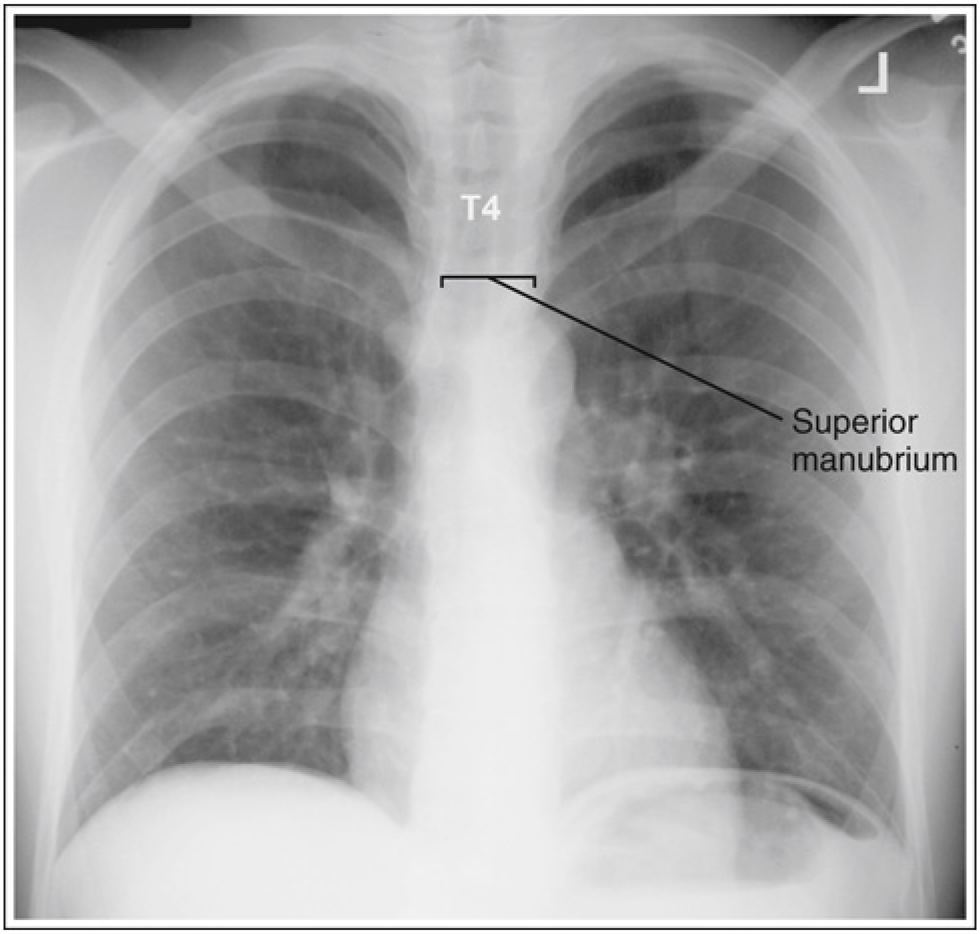


FIGURE 3.36 PA chest taken with superior midcoronal plane tilted anteriorly.

When a PA chest projection is taken with the superior midcoronal plane tilted anteriorly, the clavicles are not always demonstrated horizontally but may be seen vertically, as shown on a projection that demonstrates poor shoulder depression. Distinguish poor shoulder depression from poor midcoronal plane positioning by measuring the amount of lung field visualized superior to the clavicles and determining which vertebra is superimposed over the manubrium. A projection with poor shoulder depression demonstrates 1 inch (2.5 cm) of apical lung field above the clavicles and the manubrium at the level of the fourth vertebra (see **Fig. 3.33**). A projection with the superior midcoronal plane tilting anteriorly

demonstrates greater than 1 inch (2.5 cm) of apical lung field above the clavicles and the manubrium at a level inferior to the fourth vertebra (see **Fig. 3.36**).

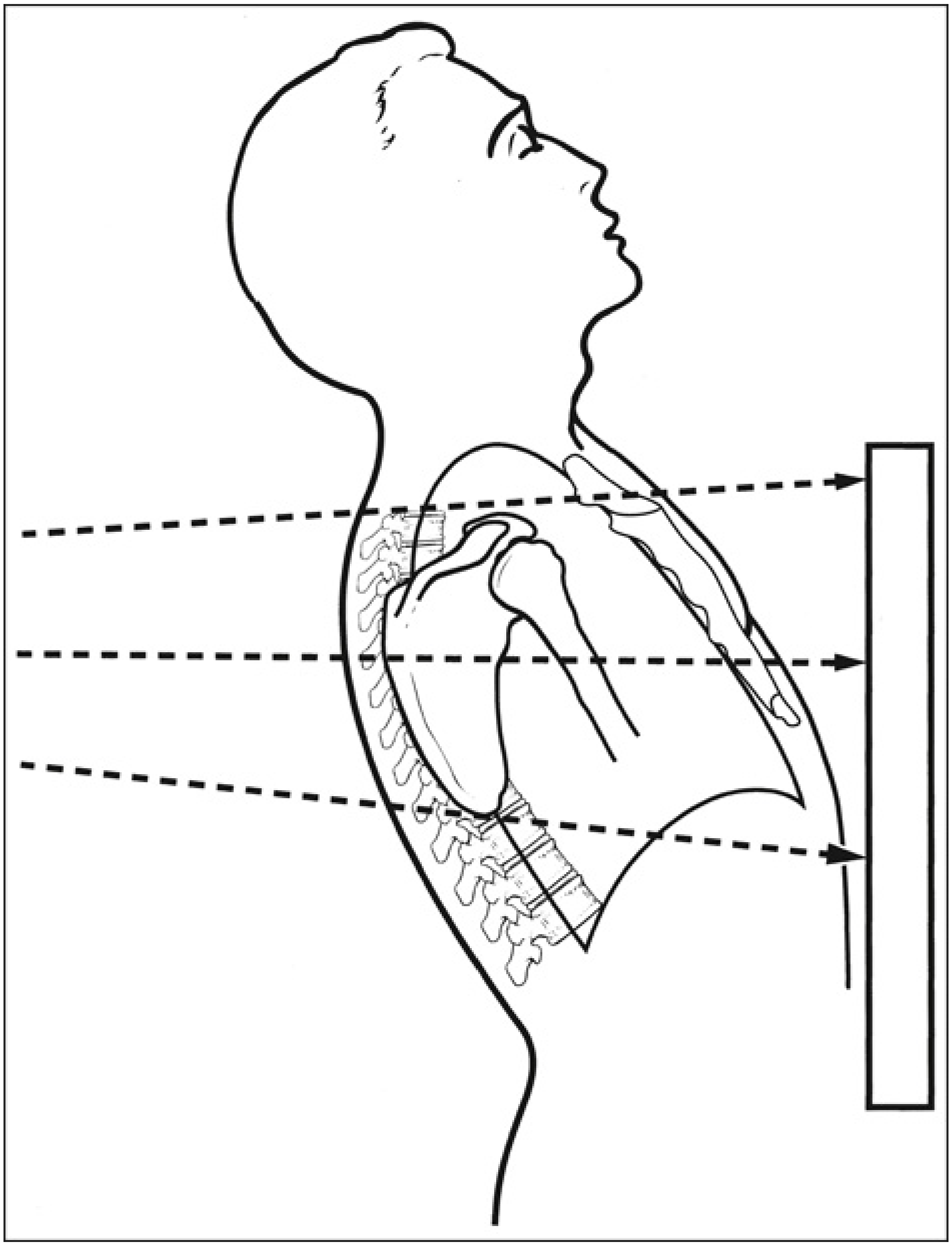


FIGURE 3.37 Superior midcoronal plane tilted posteriorly.

Posterior Midcoronal Plane Tilting

If the superior midcoronal plane is tilted posteriorly, as demonstrated in **Fig. 3.37**, the lungs and heart are foreshortened, the manubrium is situated at a level above the fourth thoracic vertebra, and less than 1 inch (2.5 cm) of the apices is demonstrated above the clavicles (**Fig. 3.38**).

Lung Aeration

On deep inspiration the lungs expand in three dimensions—transversely, anteroposteriorly, and vertically. It is the vertical dimension that will demonstrate the greatest expansion. During normal quiet breathing, the vertical dimension increases about 0.4 inches (1 cm). In high levels of breathing, as when we coax a patient into deep inspiration for a chest projection, the vertical dimension can increase by as much as 4 inches (10 cm). This full vertical lung expansion is necessary to demonstrate the entire lung field. Imaging the patient in an upright position and encouraging a deep inspiration by taking the exposure at the end of the second full inspiration allows for the demonstration of the greatest amount of vertical lung field.

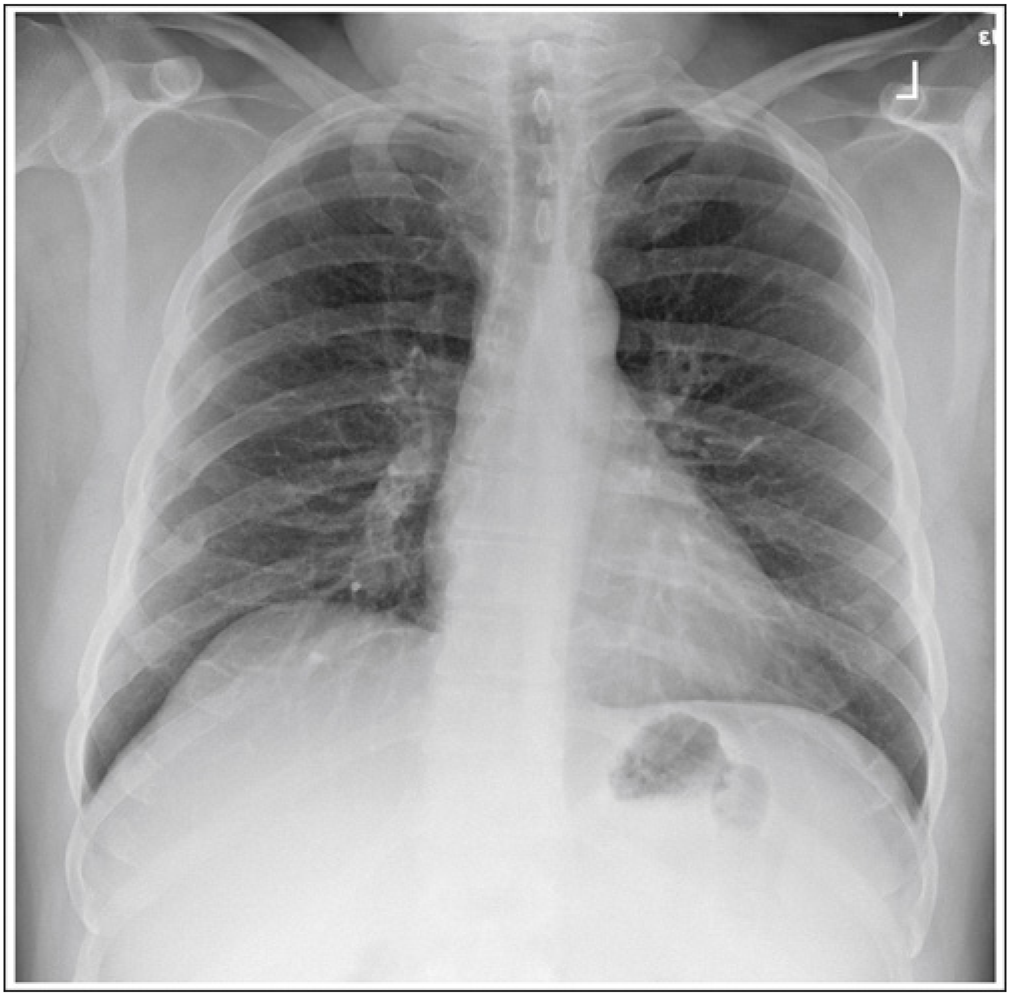


FIGURE 3.38 PA chest taken with superior midcoronal plane tilted posteriorly.

Circumstances that may prevent full lung expansion include disease processes, advanced pregnancy, excessive obesity, being seated in a slouching position, and confining abdominal clothing. If the diaphragm does not fully cover the ninth posterior ribs, the lungs were not fully inflated. Before repeating the procedure, attempt to obtain a deeper inspiration and determine whether a patient's condition might have caused the poor inhalation. Chest projections that are taken with inadequate inspiration also demonstrate a wider appearing heart shadow and an

increase in lung tissue brightness, because the decrease in air volume increases the concentration of pulmonary tissues (**Fig. 3.39**).

Expiration Chest

Abnormalities such as a pneumothorax or foreign body may indicate the need for an expiration PA chest. For such a projection, all of the image analysis guidelines listed for an inspiration PA chest should be met, except for the number of ribs demonstrated above the diaphragm. On an expiration PA chest, as few as eight posterior ribs may be demonstrated above the diaphragm, the lungs are denser, and the heart shadow is broader and shorter. When manually setting technique, because of the increased lung tissue density, it may be necessary to increase the exposure (mAs) when a PA chest is taken on expiration and lung details are of interest.

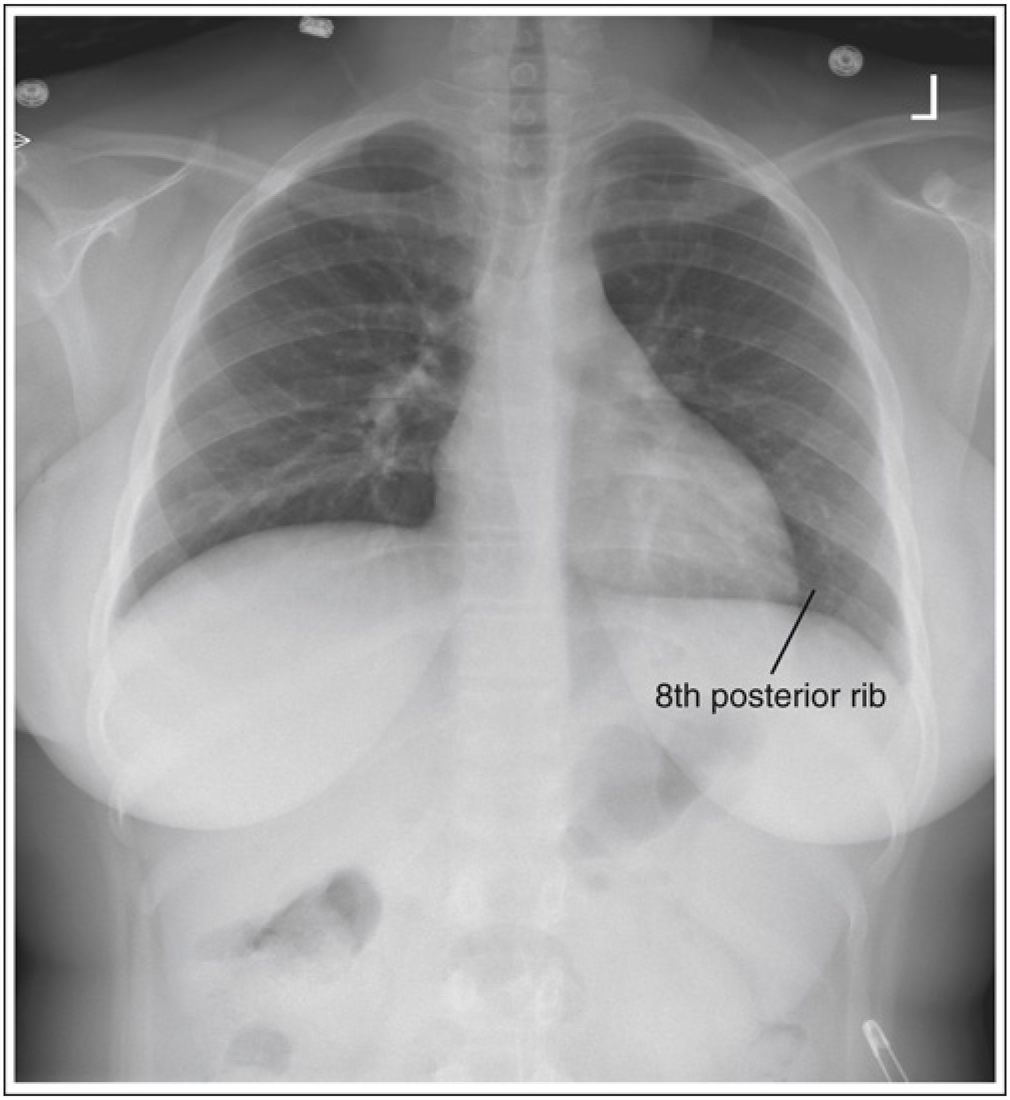


FIGURE 3.39 PA chest taken without full lung aeration.

PA Chest Analysis Practice

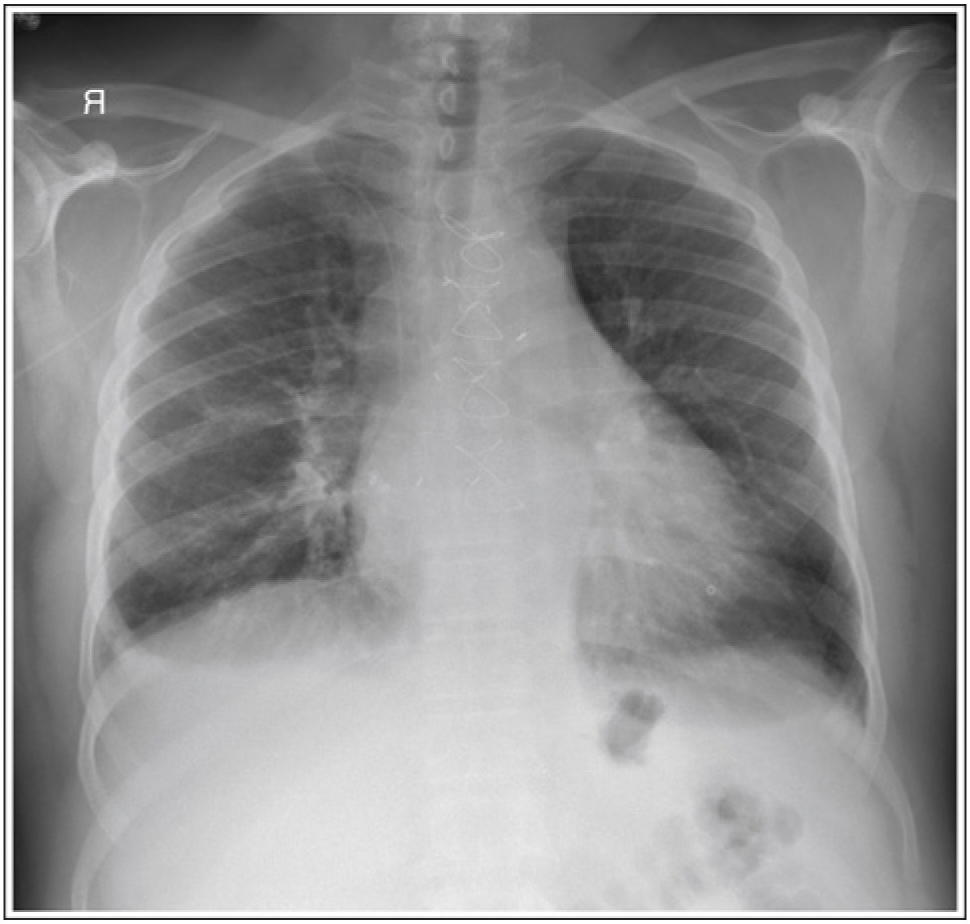


IMAGE 3.1

Analysis

The manubrium is situated at the level of the third thoracic vertebra, and less than 1 inch (2.5 cm) of the apices is demonstrated superior to the clavicles. The upper midcoronal plane was tilted posteriorly. The diaphragm is superior to the tenth posterior rib on the right side. The projection was obtained without full inspiration.

Correction

Move the upper thorax toward the IR until the midcoronal plane is parallel with the IR and coax the patient into a deeper inspiration by making the

exposure after the second full inspiration.

IMAGE 3.2

Analysis

The manubrium is situated at the level of the fifth thoracic vertebra, and more than 1 inch (2.5 cm) of the apices is demonstrated superior to the clavicles. The upper midcoronal plane was tilted anteriorly.

Correction

Move the upper thorax away from the IR until the midcoronal plane is vertical.

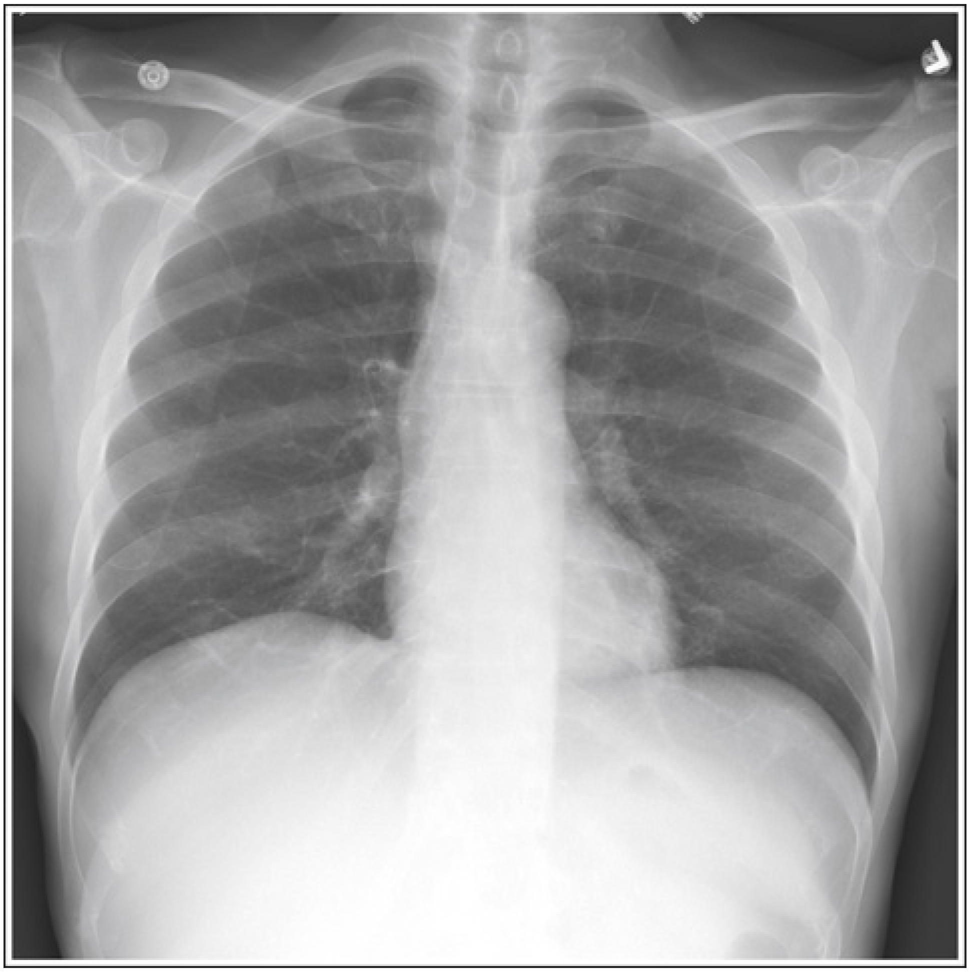


IMAGE 3.3

Analysis

The right sternal clavicular end is demonstrated farther from the vertebral column than the left. The right side of the chest was situated farther from the IR than the left side. The scapulae are in the lung fields.

Correction

Rotate the right side of the chest toward the IR until the midcoronal plane is parallel with the IR, and protract the shoulders by placing the back of the hand on the hips and rotating the elbows and shoulders anteriorly.

Chest: Lateral Projection (Left Lateral Position)

See **Table 3.4** and Figs. **3.40** and **3.41**.

Anteroinferior Lung and Heart Region Visualization

The anteroinferior lung and heart region is most clearly defined when the patient is imaged in a standing position. If the patient is seated and leaning forward, the anterior abdominal tissue is compressed, obscuring the anteroinferior lung and the heart shadow; this is especially true in an obese patient (**Fig. 3.42**). To best demonstrate this region on the seated patient, have the patient lean back slightly, allowing the anterior abdominal tissue to stretch out. Do not lean the patient so far back, however, that the posterior lungs are not on the projection. Consideration of patient condition dictates how the projection will be taken.

Chest Rotation: Midcoronal Plane Positioning

Placing the midcoronal plane perpendicular with the IR prevents chest rotation. In this position, because the right lung field and ribs are positioned at a greater OID than the left lung field and ribs, the right lung field and ribs are more magnified. This magnification prevents the right and left ribs from being directly superimposed on a lateral chest projection, demonstrating approximately a 0.5 inch (1 cm) separation between the right and left posterior ribs, with the right posterior ribs projecting behind the left (see **Fig. 3.40**). When the posterior ribs are directly superimposed, this separation is demonstrated between the anterior ribs, but it is more difficult to distinguish.

Chest rotation is effectively detected on a lateral chest by evaluating the degree of superimposition of the posterior ribs and anterior ribs. When more than 0.5 inch (1.25 cm) of space exists between the right and left posterior

ribs, the chest was rotated for the projection. A rotated lateral chest obscures portions of the lung field and distorts the heart and hilum shadows. When a rotated lateral chest has been obtained, determine how to reposition the patient by identifying the hemidiaphragms and therefore the lungs. Once the lungs have been identified, reposition the patient by rotating the thorax. When the left lung was anteriorly positioned on the original projection, rotate the left thorax posteriorly, and when the right lung was anteriorly positioned, rotate the right thorax posteriorly. Because both lungs move simultaneously, the amount of adjustment will only be half of the excessive distance demonstrated between the posterior ribs after subtracting the 0.5 inch (1.25 cm) caused by magnification.

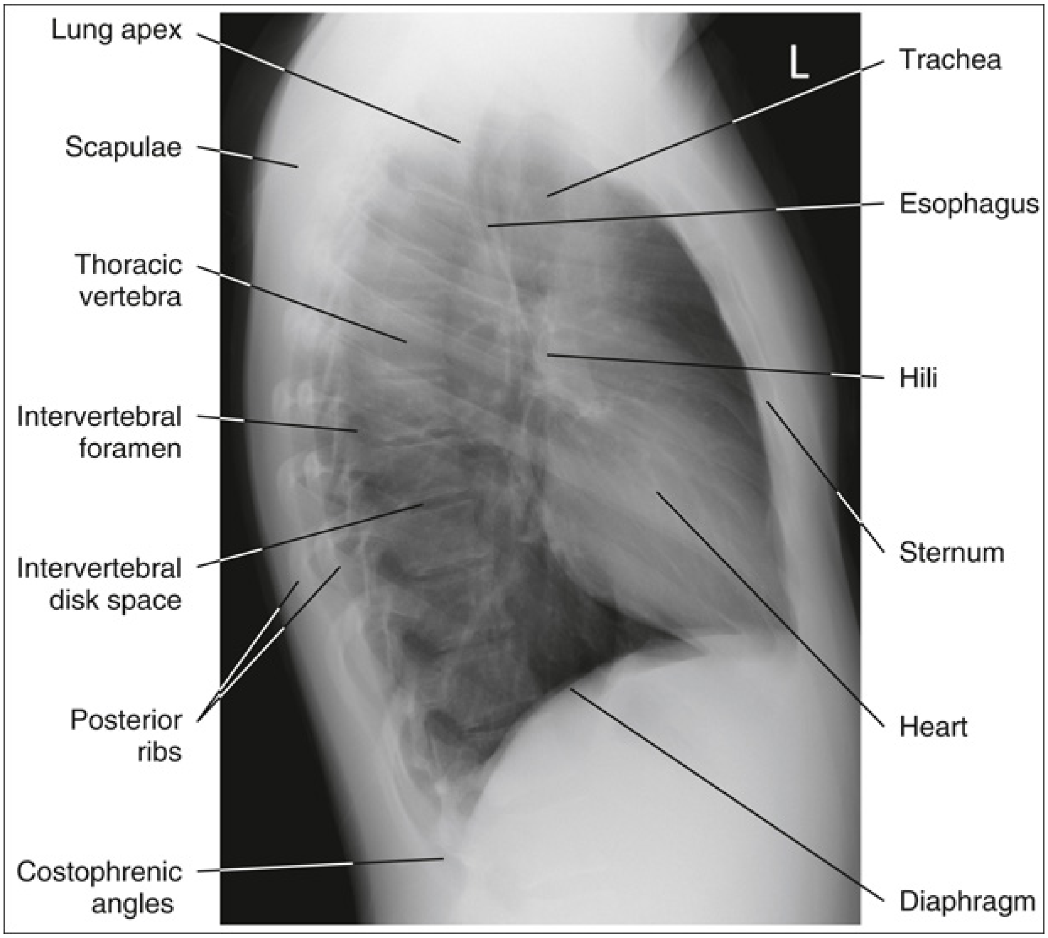


FIGURE 3.40 Lateral chest projection with accurate positioning.

TABLE 3.4

CR, Central ray; *IR*, image receptor.

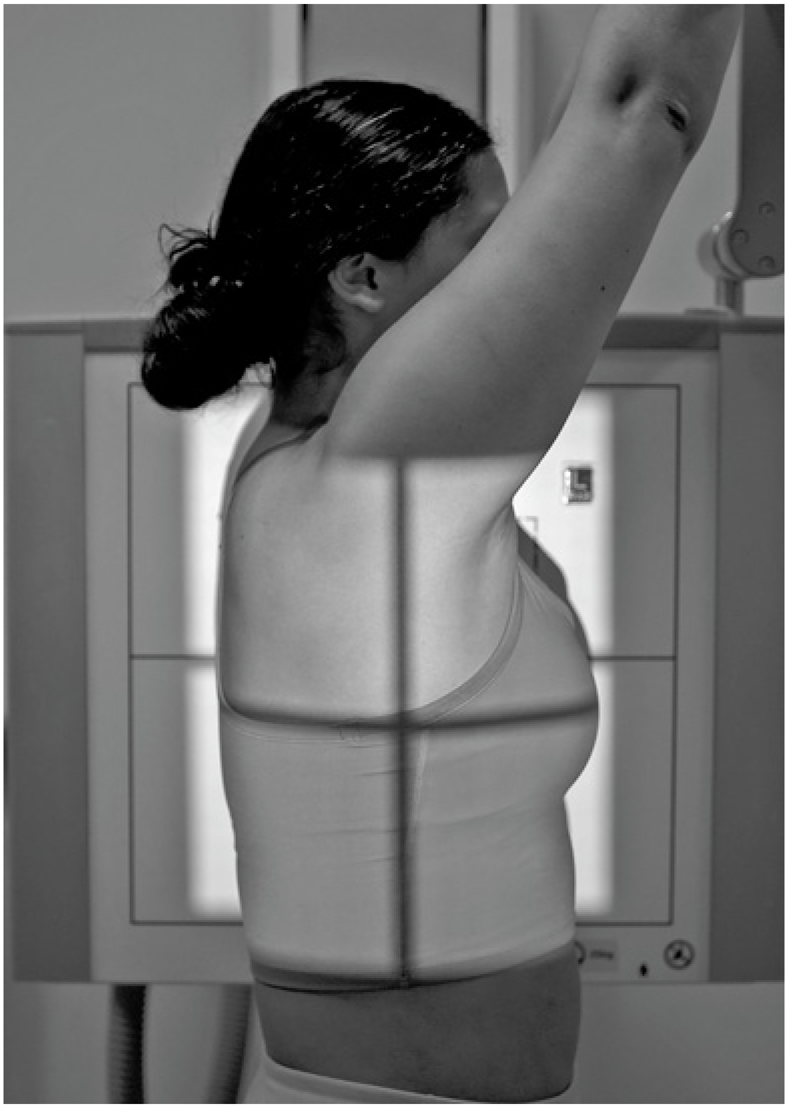


FIGURE 3.41 Proper patient positioning for lateral chest projection.

FIGURE 3.42 Lateral chest taken with anterior abdominal tissue compressing the anteroinferior lungs.

Distinguishing the Right and Left Lungs

The first method of discerning the hemidiaphragm is to identify the gastric air bubble. On an upright patient, gas in the stomach rises to the fundus, which is located just beneath the left hemidiaphragm (**Fig. 3.43**). If this

gastric bubble is visible on the projection, you know that the left hemidiaphragm is located directly above it.

The second method of distinguishing the lungs is to look for lung tissue that is anterior to the sternum (see **Fig. 3.43**). This lung tissue shows when the right lung is rotated anteriorly, and is not demonstrated when the left lung is rotated anteriorly (**Fig. 3.44**). The reason for this is that the right lung is more magnified than the left because it is at a greater OID and it takes less rotation for the lung tissue to be seen anteriorly. The amount of rotation it would take to see the left lung tissue anterior to the sternum would be great enough that the technologist could identify it during positioning.

The third method of distinguishing one lung from the other uses the heart shadow. Because the heart shadow is located in the left chest cavity and extends anteroinferiorly to the left hemidiaphragm, outlining the superior heart shadow enables you to recognize the left lung. As demonstrated in **Fig. 3.45**, if the left lung is positioned anteriorly, the outline of the superior heart shadow continues beyond the sternum and into the anterior lung (see **Fig. 3.44**). **Fig. 3.46** demonstrates the opposite rotation; the right lung is positioned anteriorly. Note how the superior heart shadow does not extend into the anterior situated lung but ends at the sternum (see **Fig. 3.43**). It is most common on rotated lateral chest projections for the left lung to be rotated anteriorly and the right lung to be rotated posteriorly.

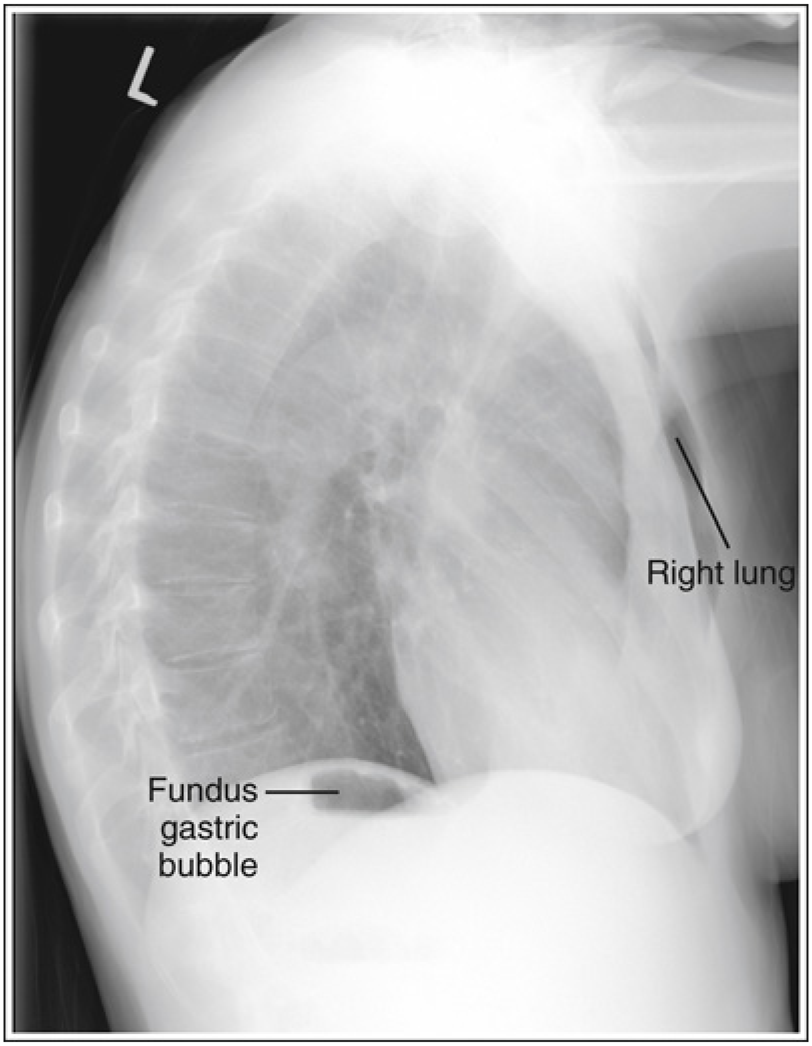


FIGURE 3.43 Lateral chest taken with right thorax rotated anteriorly.

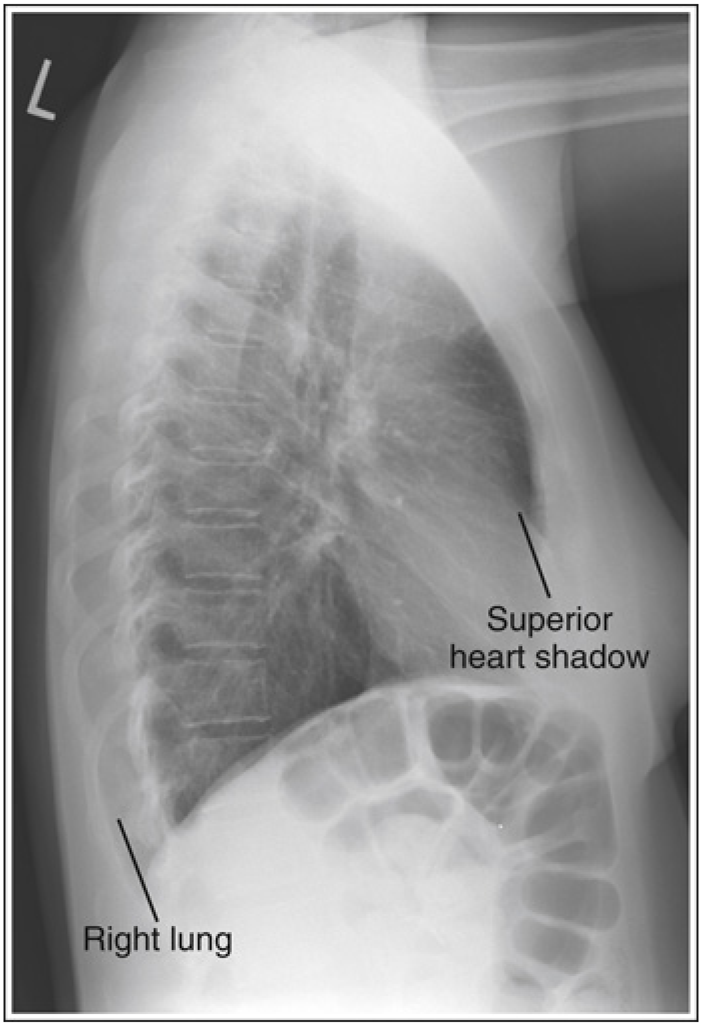


FIGURE 3.44 Lateral chest taken with right thorax rotated posteriorly.

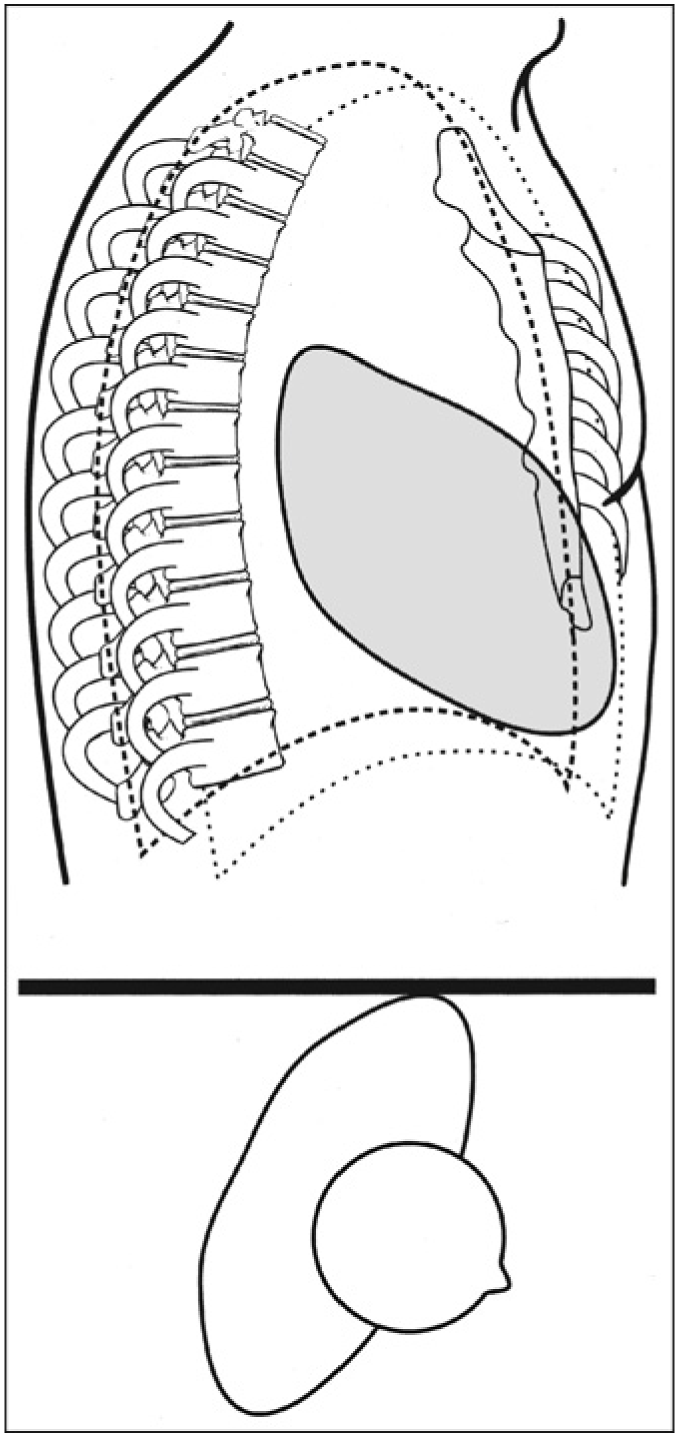


FIGURE 3.45 Rotation—left lung anterior.

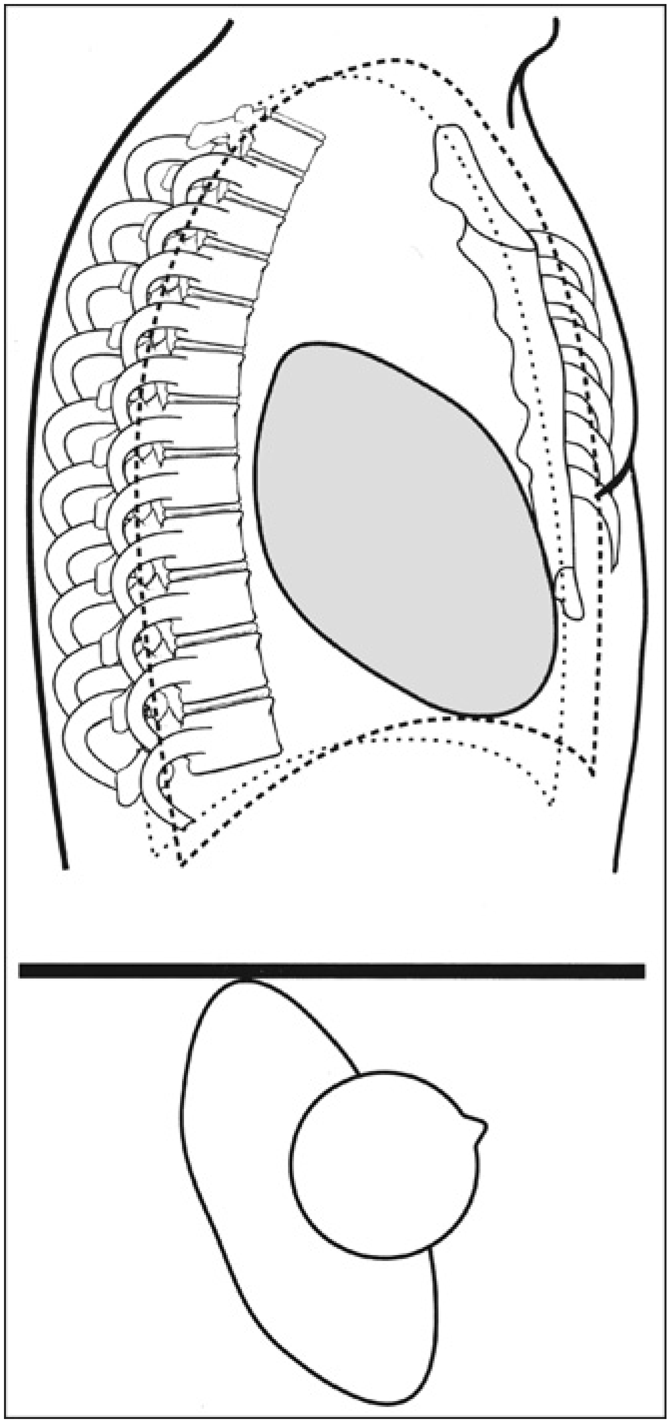


FIGURE 3.46 Rotation—right lung anterior.

Distinguishing Scoliosis From Rotation

On lateral chests of patients with spinal scoliosis, the lung field may appear rotated because of the lateral deviation of the vertebral column (**Fig. 3.47**). The scoliotic patient will demonstrate superimposed anterior ribs, but the posterior ribs demonstrate differing degrees of separation, depending on the severity of scoliosis. When scoliosis is suspected, view the accompanying PA chest projection to confirm this patient condition. Although the separation between the posterior ribs is not acceptable beyond 0.5 inch (1.25 cm) on a patient without scoliosis, it is acceptable on a patient with the condition.

Midsagittal Plane Tilting and Lung Foreshortening

To obtain a lateral chest without lung foreshortening, the midsagittal plane is aligned parallel with the IR. When imaging a patient with broad shoulders and narrow hips, it may be necessary to place the hips away from the IR to maintain a parallel midsagittal plane. In 90% of persons, the right lung and diaphragm are situated at a slightly higher elevation than the left lung and diaphragm. This elevation is caused by the liver, which is situated directly below the right diaphragm and prevents the right hemidiaphragm from lowering as far as the left hemidiaphragm. Because the right diaphragm is elevated, one might expect it to be demonstrated above the left diaphragm when the patient is imaged in a left lateral projection, but this is not true when the midsagittal plane is correctly positioned. Because the anatomic part positioned farthest from the IR diverges and magnifies the most, the right lung will be projected and magnified more than the left lung, resulting in near superimposition of the two hemidiaphragms. When the midsagittal plane has not been positioned parallel with the IR, lung foreshortening and poor hemidiaphragm positioning occur.

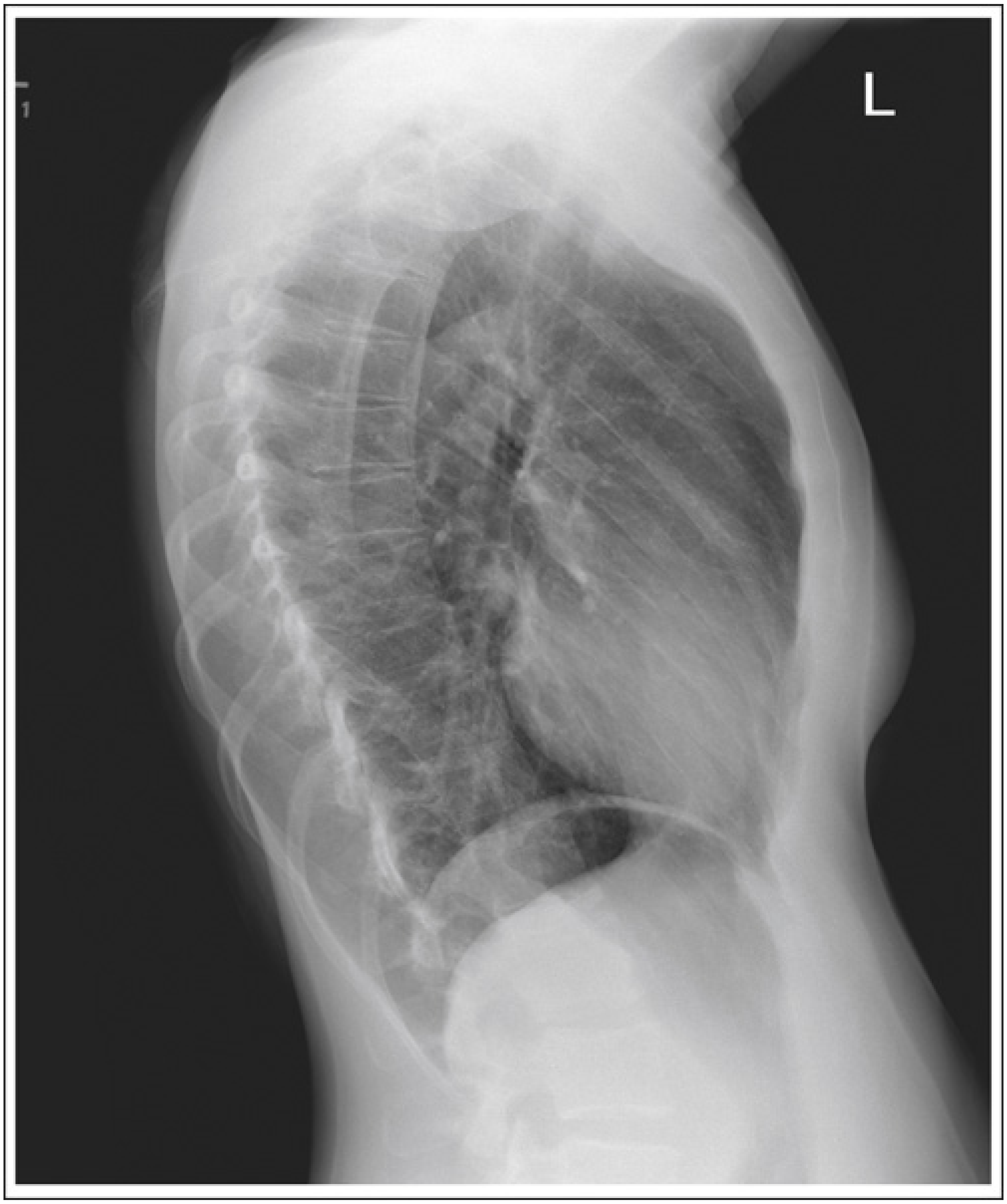


FIGURE 3.47 Lateral chest on patient with scoliosis.

Fig. 3.48 demonstrates lateral chest positioning in which the shoulders and hips were both resting against the IR, causing the inferior midsagittal plane to tilt toward the IR. This positioning projects the right hemidiaphragm inferior to the left (**Fig. 3.49**). When a projection has been obtained that demonstrates the right hemidiaphragm situated inferior to the

left, determine how the patient was mispositioned by using one of the methods described earlier to distinguish the right lung from the left lung.

Before repeating a lateral chest because of poor hemidiaphragm alignment, scrutinize the accompanying PA projection to determine whether the patient is one of the 10% of those whose hemidiaphragms are at the same height or whether a pathologic condition is causing the left hemidiaphragm to be projected above the right (**Fig. 3.50**).

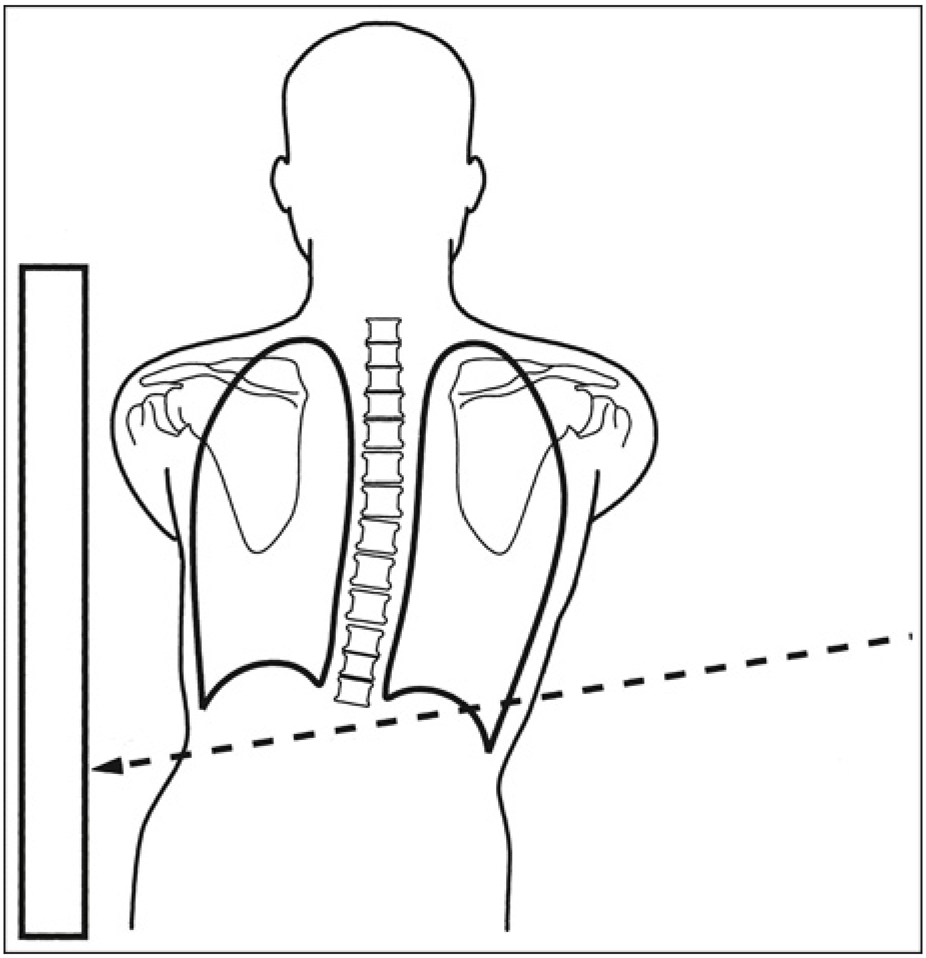


FIGURE 3.48 Lateral chest positioning with poor midsagittal plane and IR alignment.

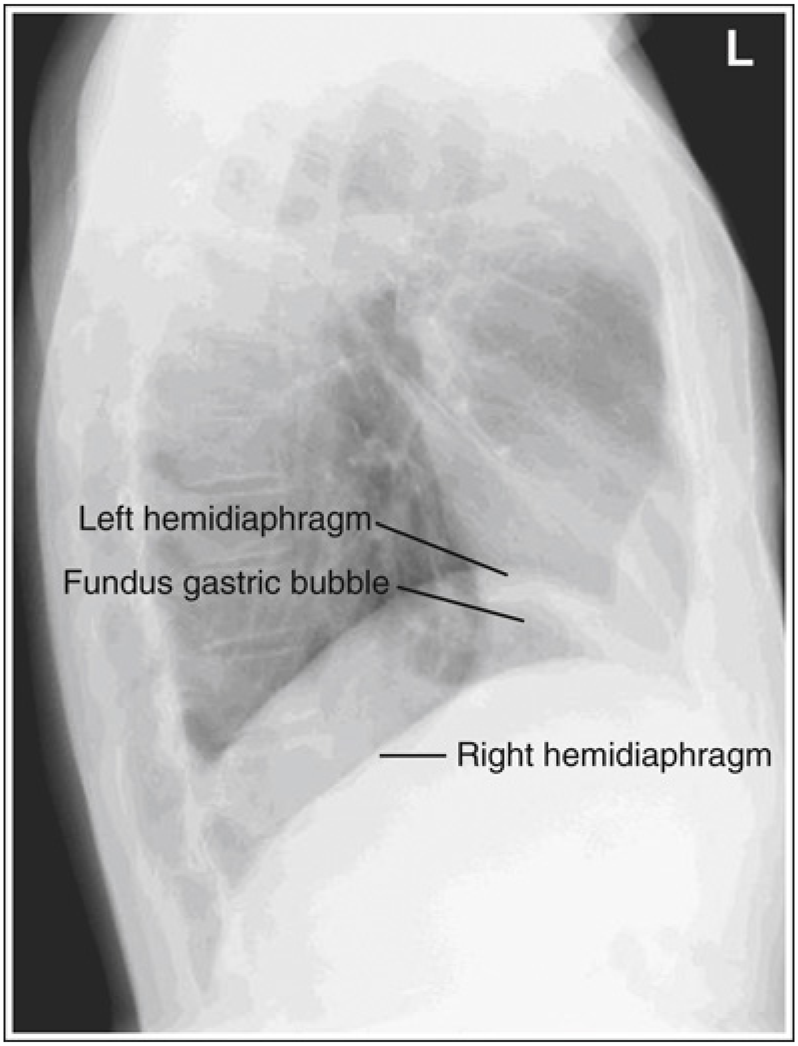


FIGURE 3.49 Lateral chest taken with inferior midsagittal plane tilted toward IR.

Right Lateral Chest Projection

A left lateral chest and right lateral chest have two distinct differences: the size of the heart shadow and the superimposition of the hemidiaphragms. Both differences are a result of a change in OID and magnification. For a right lateral, the right thorax is positioned closer to the IR. In this position, any anatomic structures located in the right thorax are magnified less than structures located in the left thorax because of the difference in OID.

Radiographically, the heart shadow is more magnified and the left hemidiaphragm projects lower than the right hemidiaphragm (**Fig. 3.51**). One advantage of obtaining a right rather than a left lateral chest is the increase in right lung radiographic detail that results from positioning of the right lung closer to the IR.

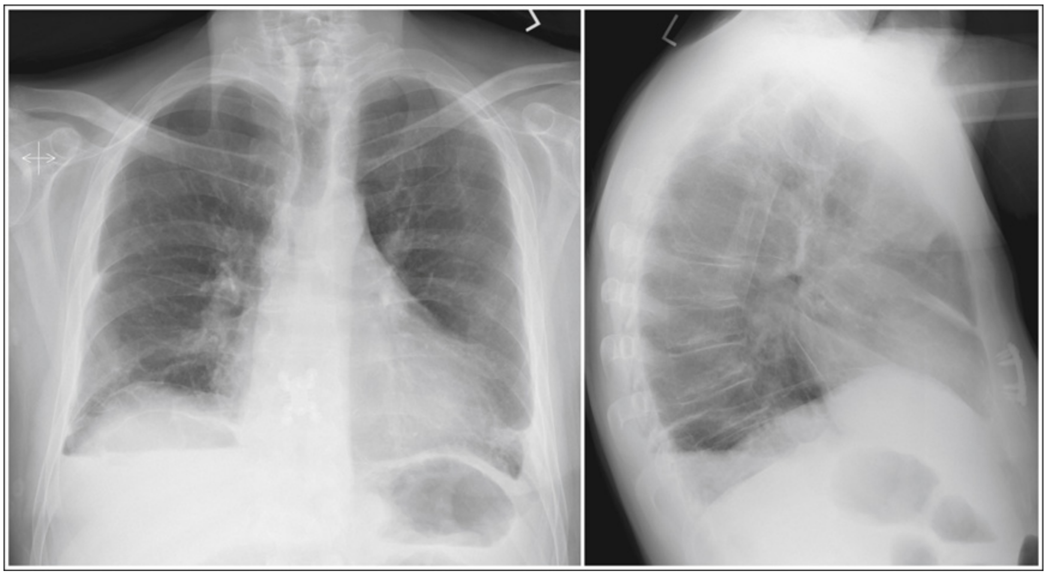


FIGURE 3.50 PA and lateral chest with accurate positioning that demonstrates hemidiaphragms at different levels due to a pathologic condition.

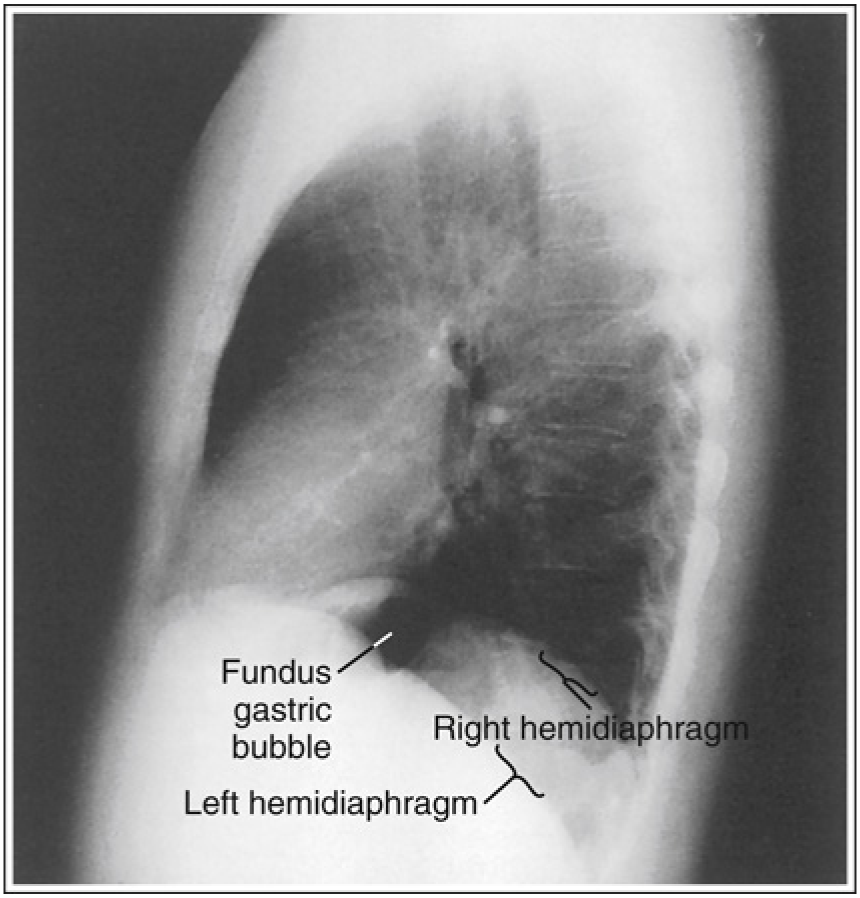


FIGURE 3.51 Right lateral chest projection with accurate positioning.

Arm Positioning and Anterior Lung Visualization

Accurate arm positioning prevents superimposition of the humeral soft tissue over the anterior lung apices (**Fig. 3.52**). Many dedicated chest units provide holding bars for the arms. When they are used, the humeri should be placed high enough to prevent this soft tissue overlap. If the holding bars cannot be raised enough, position the humeri in an upright vertical position with the forearms crossed and resting on the head. To prevent patient motion with this arm placement, evenly distribute the weight on the feet and lightly rest the left shoulder against IR.

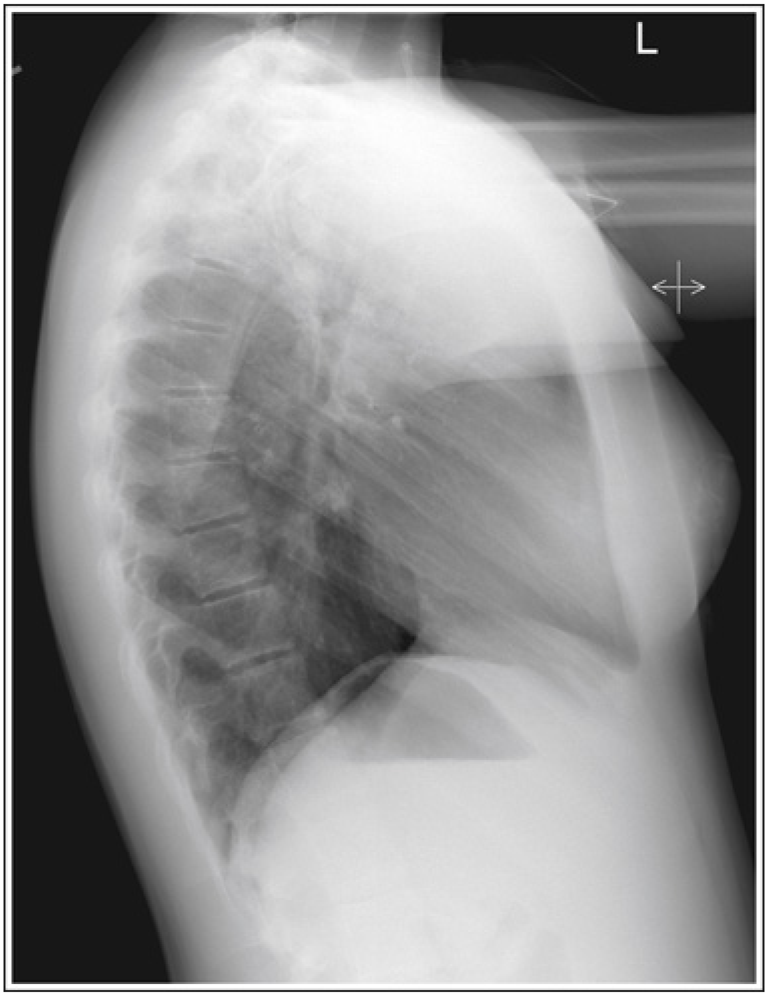


FIGURE 3.52 Lateral chest taken with humeri not elevated.

Maximum Lung Aeration

Full lung aeration has been accomplished when the hemidiaphragms are inferior to the eleventh thoracic vertebra. When a lateral chest demonstrates the hemidiaphragms with an exaggerated cephalic bow (in addition to a portion of the eleventh thoracic vertebra demonstrated inferior to the hemidiaphragms) and the patient has no condition to have caused such a projection, full lung aeration has not been accomplished (**Fig. 3.53**). Repeat the procedure after coaxing the patient into a deeper inspiration. The lungs

must be fully inflated for lung markings to be evaluated. Chest projections taken on expiration may also demonstrate an increase in brightness, because a decrease in air volume increases the concentration of pulmonary tissues.

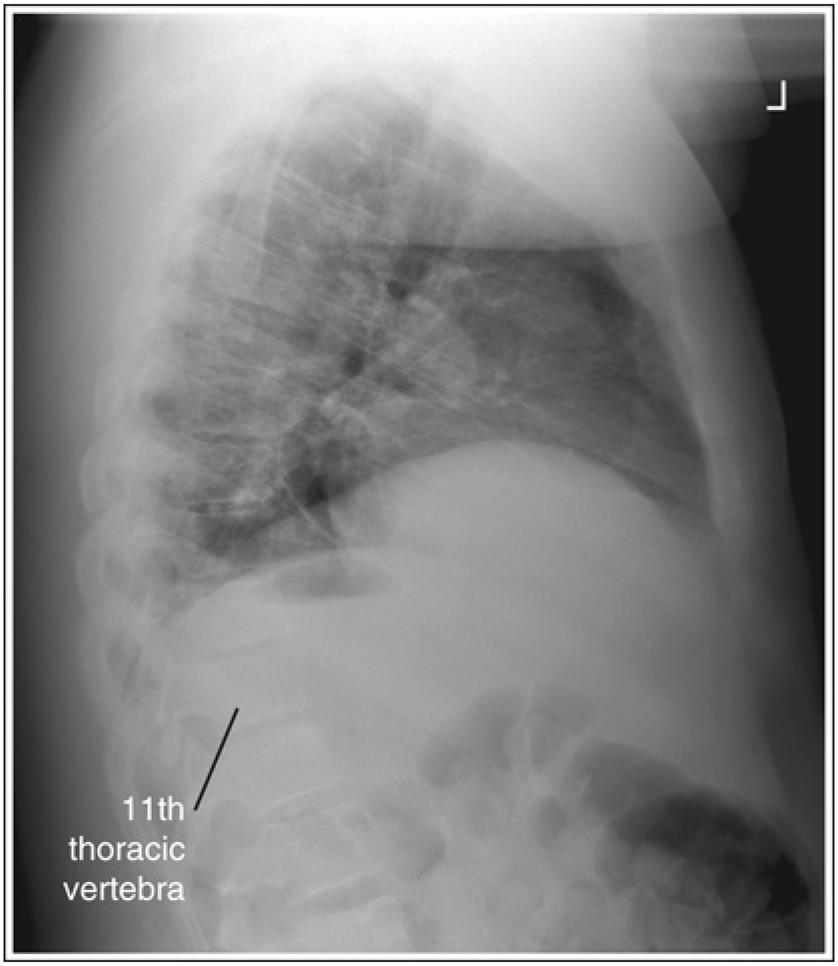


FIGURE 3.53 Lateral chest without full lung aeration.

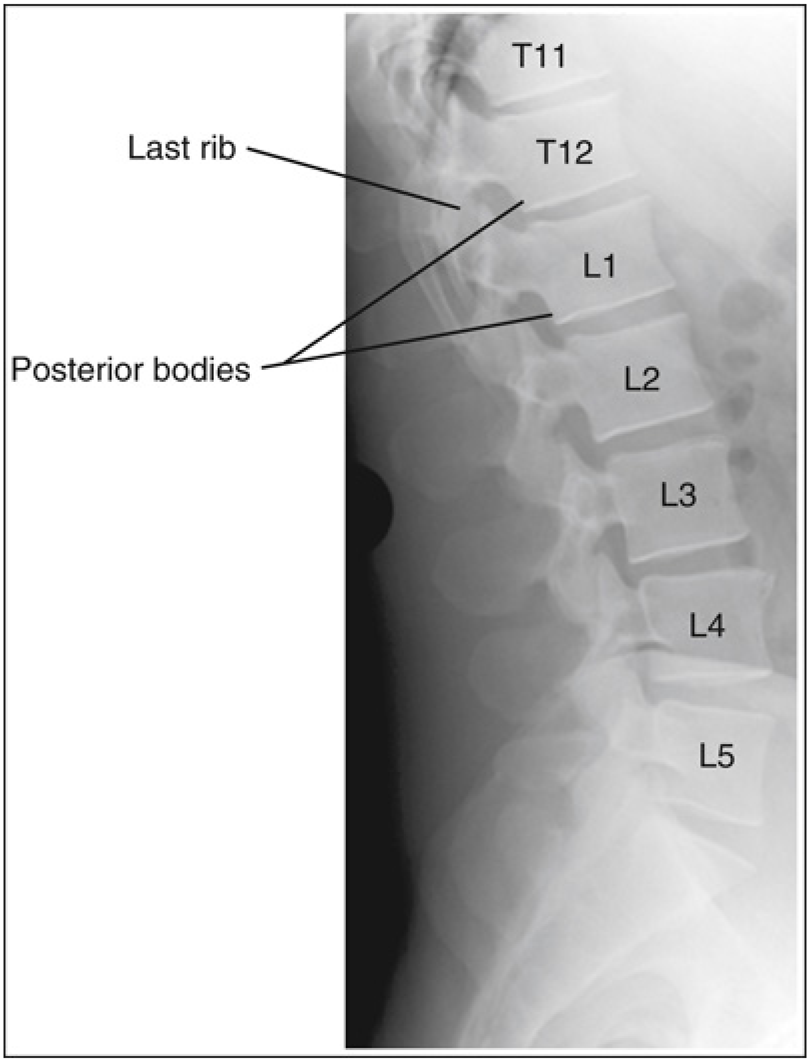


FIGURE 3.54 Identifying the twelfth thoracic vertebra.

Identifying the Eleventh Thoracic Vertebra

The eleventh thoracic vertebra can be identified by locating the twelfth thoracic vertebra, which has the last rib attached to it, and counting up one. To confirm this finding, evaluate the curvature of the posterior aspect of the thoracic and lumbar bodies. The thoracic curvature is kyphotic (forward curvature), and the lumbar curvature is lordotic (backward curvature). Follow the posterior vertebral bodies of the lower thoracic and upper

lumbar vertebrae, watching for the subtle change in curvature from kyphotic to lordotic. The twelfth thoracic vertebra is located just above this change (**Fig. 3.54**). On most fully aerated adult lateral chest projections, the diaphragms are demonstrated dividing the body of the twelfth thoracic vertebra.

Lateral Chest Analysis Practice

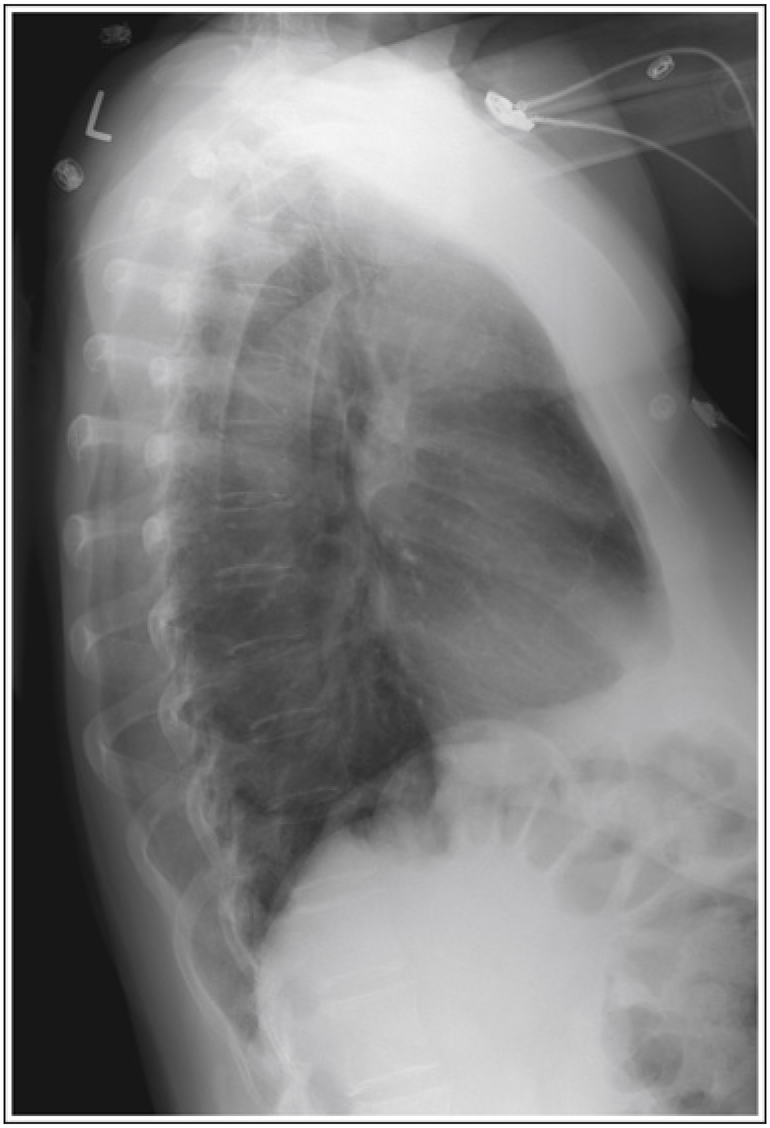


IMAGE 3.4

Analysis

The right and left posterior ribs are separated by more than 0.5 inch (1.25 cm), indicating that the chest was rotated. Lung tissue is not demonstrated anterior to the sternum. The patient was positioned with the left thorax rotated anteriorly and the right thorax rotated posteriorly. The humeral soft tissue shadows are obscuring the anterior lung apices.

Correction

Position the right thorax anteriorly. The amount of movement should be only half the distance between the posterior ribs after subtracting the 0.5 inch (1.25 cm) caused by magnification. Have the patient raise the arms until the humeri are vertical, removing them from the exposure field.

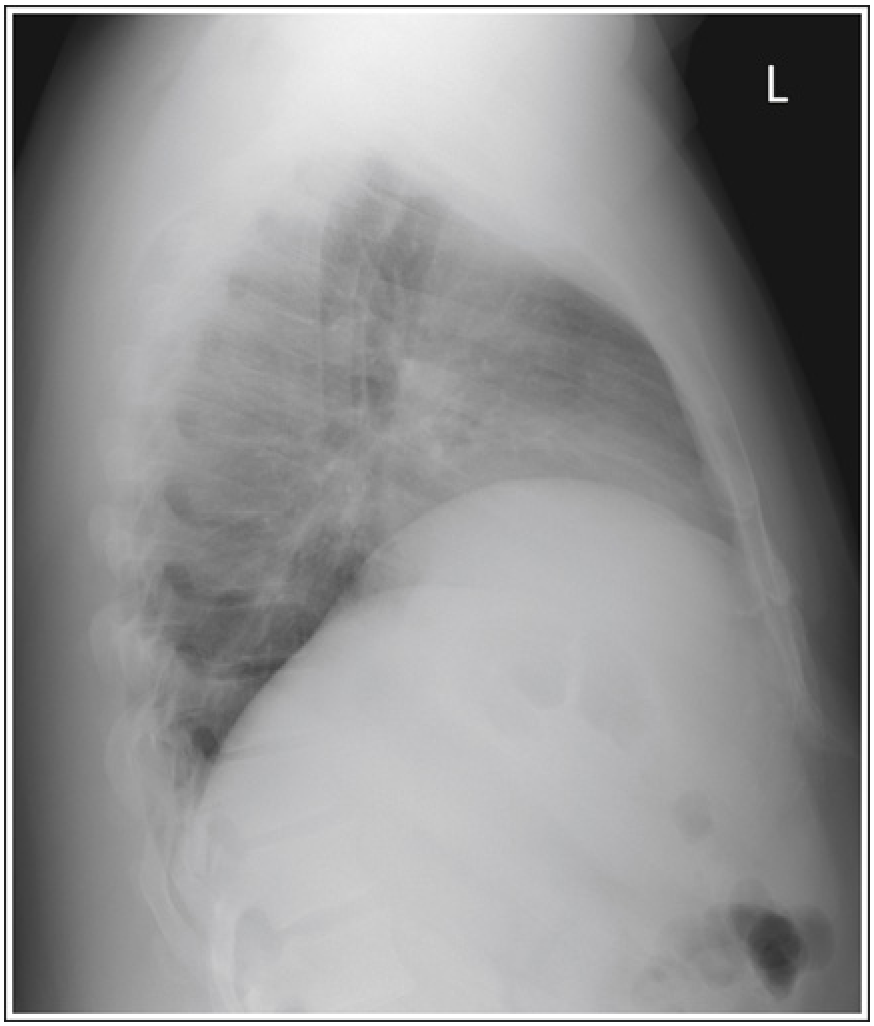


IMAGE 3.5

Analysis

The hemidiaphragms demonstrate an exaggerated cephalic bow, and the eleventh thoracic vertebra is demonstrated inferior to the hemidiaphragms. The projection was not taken after full inspiration.

Correction

Coax the patient into a deeper inspiration by making the exposure after the second full inspiration.

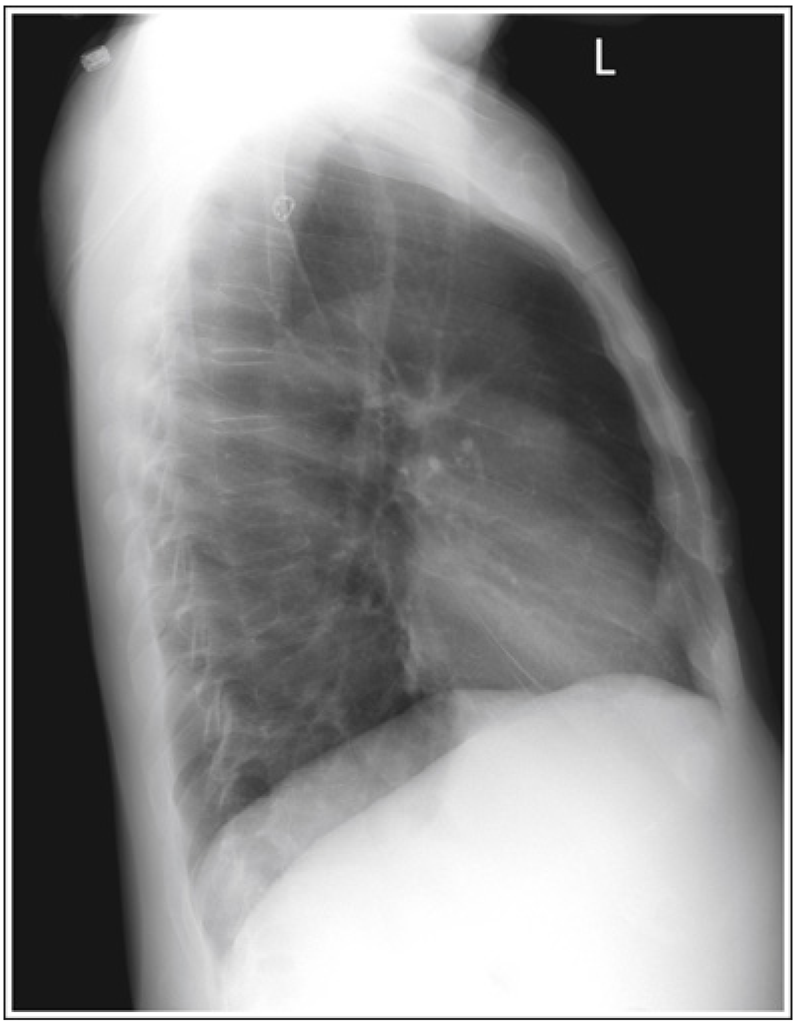


IMAGE 3.6

Analysis

The hemidiaphragms are not superimposed.

Correction

Scrutinize the accompanying PA projection carefully. Determine whether the diaphragms are at the same height or whether a pathologic condition might have caused one diaphragm to be projected above the other. If no such condition is evident, shift the hips away from the IR until the midsagittal plane is parallel with the IR before repeating the projection.

Chest: AP Projection (Supine or With Mobile X-Ray Unit)

See **Table 3.5** and Figs. **3.55** and **3.56**.

Demographic and Positioning Data

Patients in intensive care units often have mobile chest projections taken on a daily basis that are compared for subtle changes. Consistent positioning is important to ensure that the subtle changes are not caused by poor positioning or technical factors, but is difficult to obtain when follow-up projections are performed by multiple technologists. Consistency can best be accomplished through proper documentation. To do this, radiology departments have ways to electronically annotate the information on the projection or in the patient's records. At a minimum, the information should include the date and time of examination, the SID used, the degree of patient elevation, and the technical factors used. The technologist reviews this information prior to obtaining a subsequent chest projection.

Heart Magnification: SID

The 50- to 60-inch (125- to 150-cm) SID used for AP chest projections, compared to the 72-inch (180-cm) used for routine PA chest projections, results in projections that demonstrate greater heart magnification, owing to the increase in x-ray divergence caused by using the shorter SID. The SID is often estimated during mobile procedures, but if available, using the tape measure attached to the x-ray tube to maintain appropriate SID provides consistency in magnification and reduces the need to adjust technical factors.

Heart Magnification: AP Versus PA Projection

The AP projection will demonstrate increased heart magnification compared to a PA projection because the heart is positioned closer to the IR and a lower SID is used.

Chest Rotation: Side-to-Side CR Alignment

In the AP chest projection, chest rotation is caused by poor transverse IR balance or poor side-to-side (lateral-to-lateral) CR alignment. To prevent chest rotation, align the transverse axis of the IR and midcoronal plane parallel with the bed (see **Fig. 3.56**). On beds with special padding, it may be necessary to place positioning aids beneath the side(s) of the IR to raise and level it. After the IR has been placed, adjust the cephalic-caudal angle of the CR until it is perpendicular to the longitudinal axis of the IR and midcoronal plane. Once this has been set up, the transverse IR axis and midcoronal plane parallelism with the bed is assessed. This is best judged by observing from behind the x-ray tube, looking straight at the patient. Poor side-to-side CR alignment projects the manubrium and clavicles in the direction that the CR is angled, causing the manubrium and the sternal ends of the clavicles to be situated more toward the right or left side of the vertebral column and rotation to be demonstrated (**Fig. 3.57**). Rotation is

identified on an AP chest by evaluating the distances between the vertebral column and the sternal ends of the clavicles, and by comparing the lengths of the posterior ribs. When the right sternal clavicular end demonstrates no superimposition of the vertebral column and the right posterior ribs demonstrate greater length than the left, the CR was angled toward the right side (see **Fig. 3.57**).

TABLE 3.5

CW, Crosswise; *LW*, lengthwise; *SID*, source–image receptor distance.

When the right sternal clavicular end is seen superimposing the vertebral column and the right side demonstrates less posterior rib length than the left, the CR was angled toward the left side of the patient (**Fig. 3.58**).

Excessive Caudal CR Angulation

The cephalic-caudal alignment of the CR with respect to the patient determines the relationship of the manubrium to the thoracic vertebrae, the amount of apical lung field seen above the clavicles, and the contour of the posterior ribs. For accurate alignment of this anatomy, position the CR perpendicular to the longitudinal axis of the IR and midcoronal plane. Inaccurate cephalic-caudal CR angulation misaligns this anatomy and distorts the heart and lung structures. The anatomic structures positioned farthest from the IR will move the greatest distance when the CR is angled, so angling the CR too caudally for an AP chest projection moves the manubrium inferior to the fourth thoracic vertebra, demonstrating more than 1 inch (2.5 cm) of lung apices superior to the clavicles, and changes

the posterior rib contour to vertical. A caudal angle also elongates the heart and lung structures (**Fig. 3.59**).

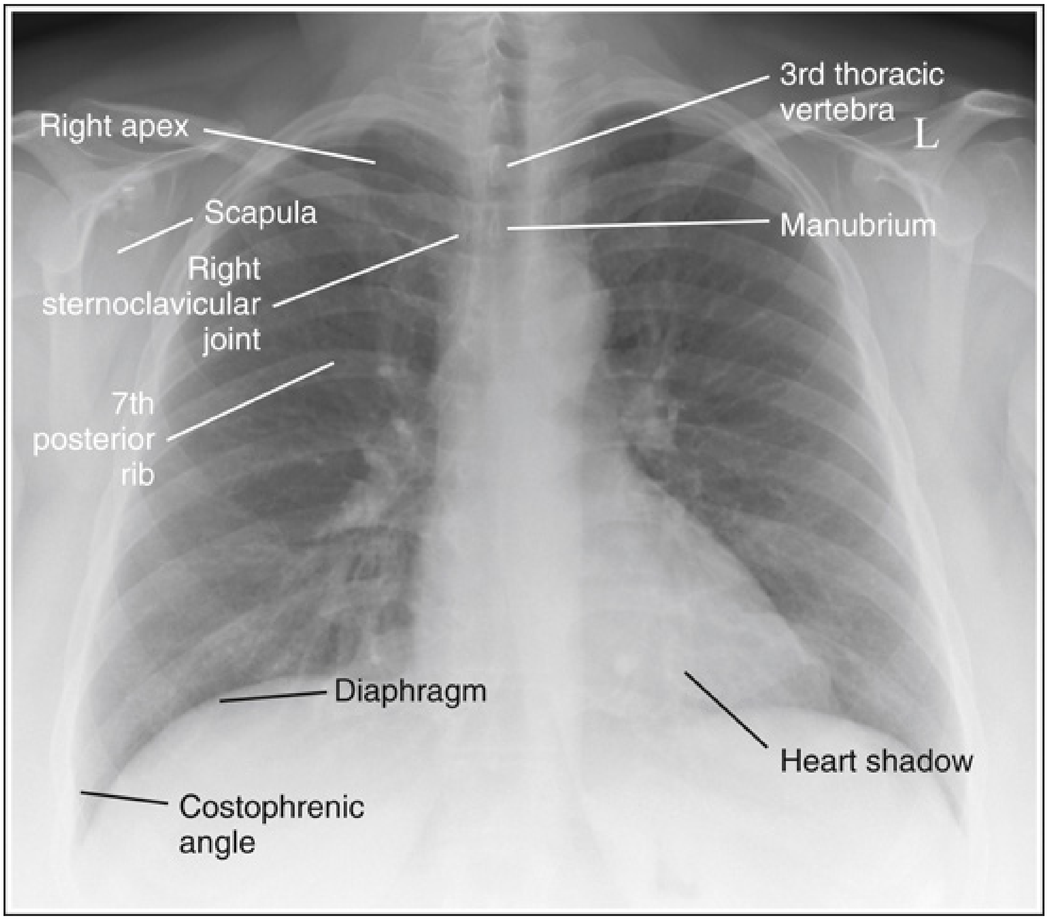


FIGURE 3.55 AP chest projection with accurate positioning.

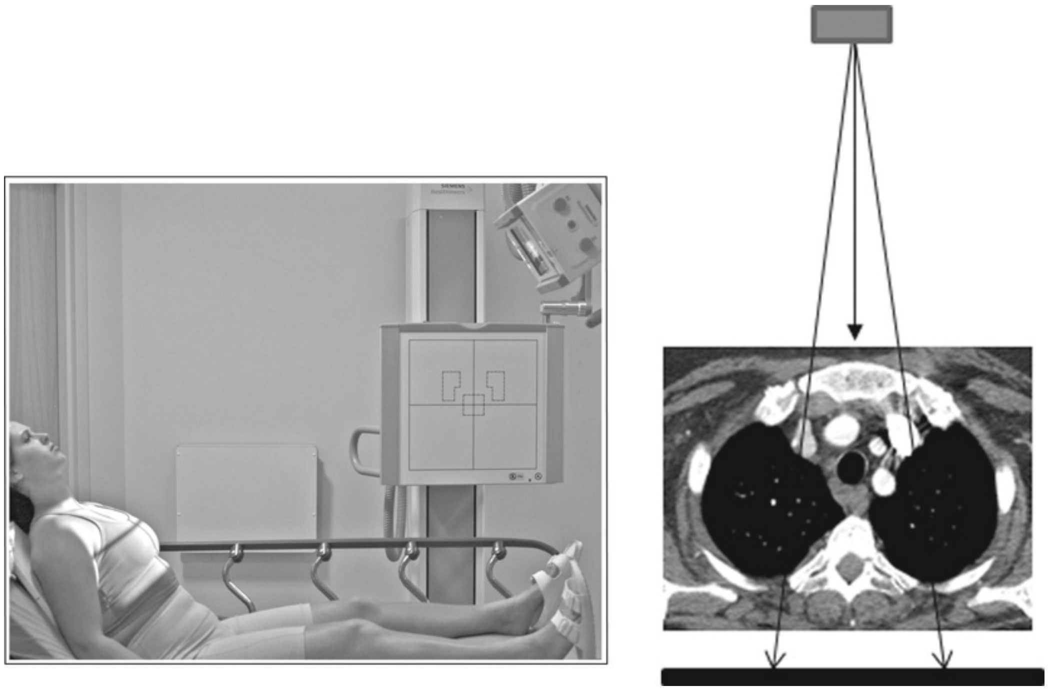


FIGURE 3.56 Proper patient positioning for an AP chest projection. The axial CT slice was obtained at a level where the manubrium and sternal clavicular ends connect. When the patient is in an AP projection and the CR is perpendicular to the transverse axis of the IR and midcoronal plane, the sternal clavicular ends are at equal distances from the vertebral column.

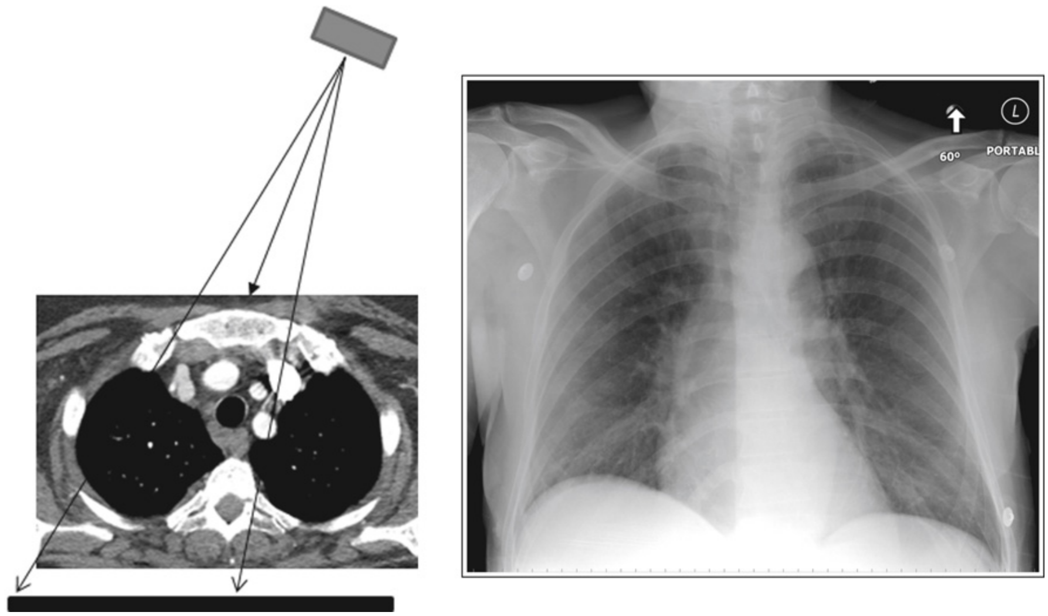


FIGURE 3.57 AP chest projection taken with the CR angled toward the right side as demonstrated on the axial CT slice, causing the manubrium and sternal clavicles to be projected to the right and demonstrating rotation on the resulting projection.

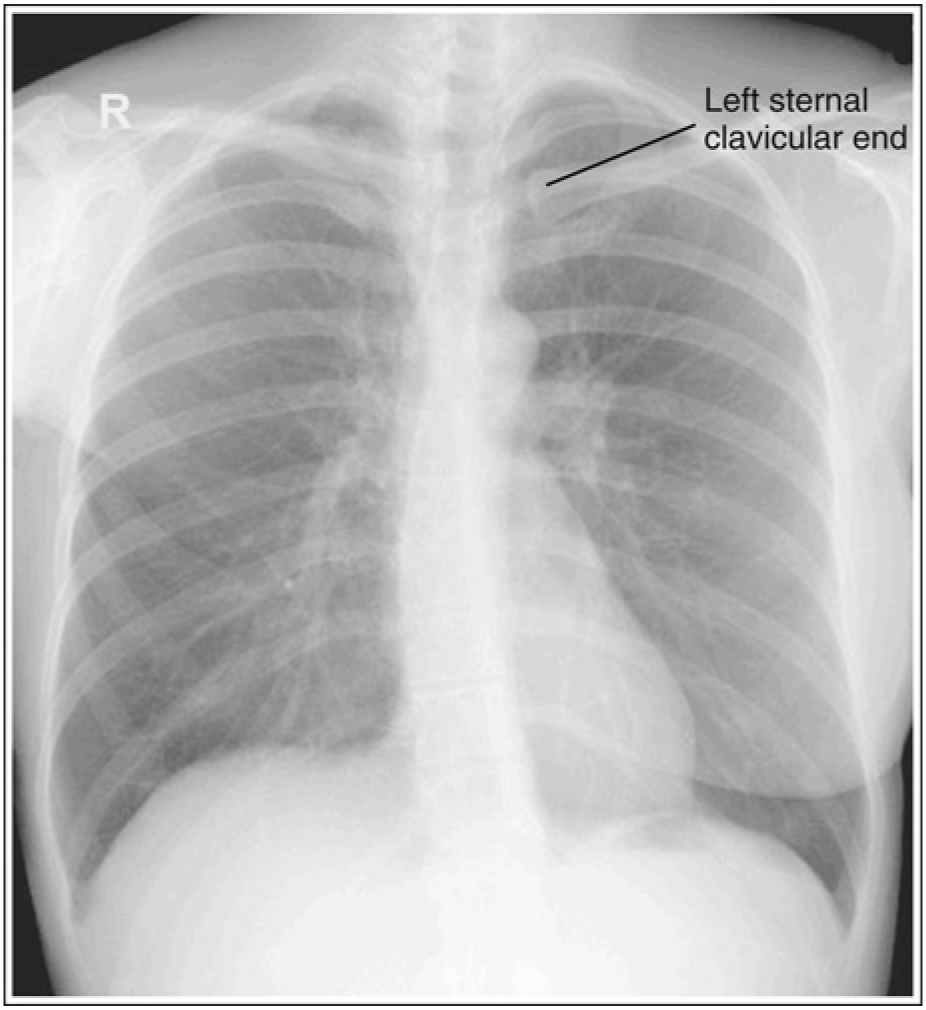


FIGURE 3.58 AP chest taken with the CR angled toward the left side, causing the resulting projection to demonstrate rotation.

Excessive Cephalic CR Angulation

Angling the CR too cephalically for an AP chest projection projects the manubrium superior to the fourth thoracic vertebra, demonstrating less than 1 inch (2.5 cm) of lung apices superior to the clavicles, and changes the posterior rib contour to horizontal. A cephalic angle also foreshortens the heart and lung structures (**Fig. 3.60**). The more the CR angulation is

mispositioned, either caudally or cephalically, the more distorted the anatomy.

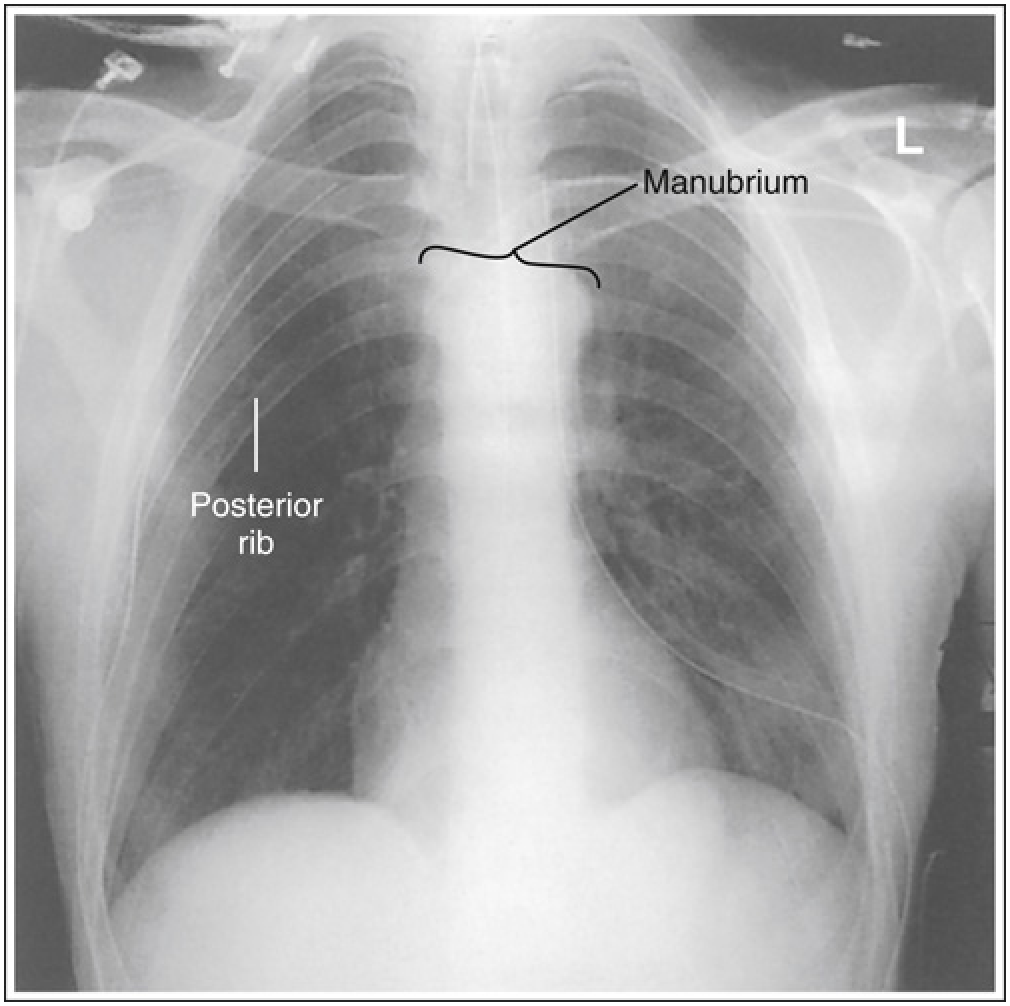


FIGURE 3.59 AP chest taken with CR angled too caudally.

Positioning for Spinal Kyphosis

The thoracic spine demonstrates kyphosis. This curve can become exaggerated to get the impression of rounded shoulders (expression for mild kyphosis) or a rounded back or hunchback (expressions for severe

kyphosis). This condition can be caused by poor posture and ergonomics, an injury, collapsed vertebra, and degenerative changes. The kyphotic patient's increase in spinal convexity prevents the upper midcoronal plane from being straightened and positioned parallel with the IR and the patient from extending the neck enough to position parts of the mandible and face superior to the apices and outside of the collimated field. As a result, AP/PA chest projections obtained with the patient positioned as close to the routine for the projection as the patient can accommodate may demonstrate the manubrium situated inferior to the fourth thoracic vertebrae and the chin and apices superimposing (**Figure 3.61**). There are alternative positioning methods to better demonstrate the apices on a kyphotic patient. One method keeps the midcoronal plane parallel with the IR and uses a 5- to 10-degree cephalic CR angulation. This angle will project the chin and manubrium cephalically and demonstrate the posterior ribs similar to those on a nonkyphotic chest projection. The second method is to lean the shoulders and upper thoracic vertebrae posteriorly to place the midcoronal plane at an angle with the IR and use a horizontal CR (**Fig. 3.62**). Note that although the apices are better demonstrated, the other chest areas demonstrate foreshortening with these methods.

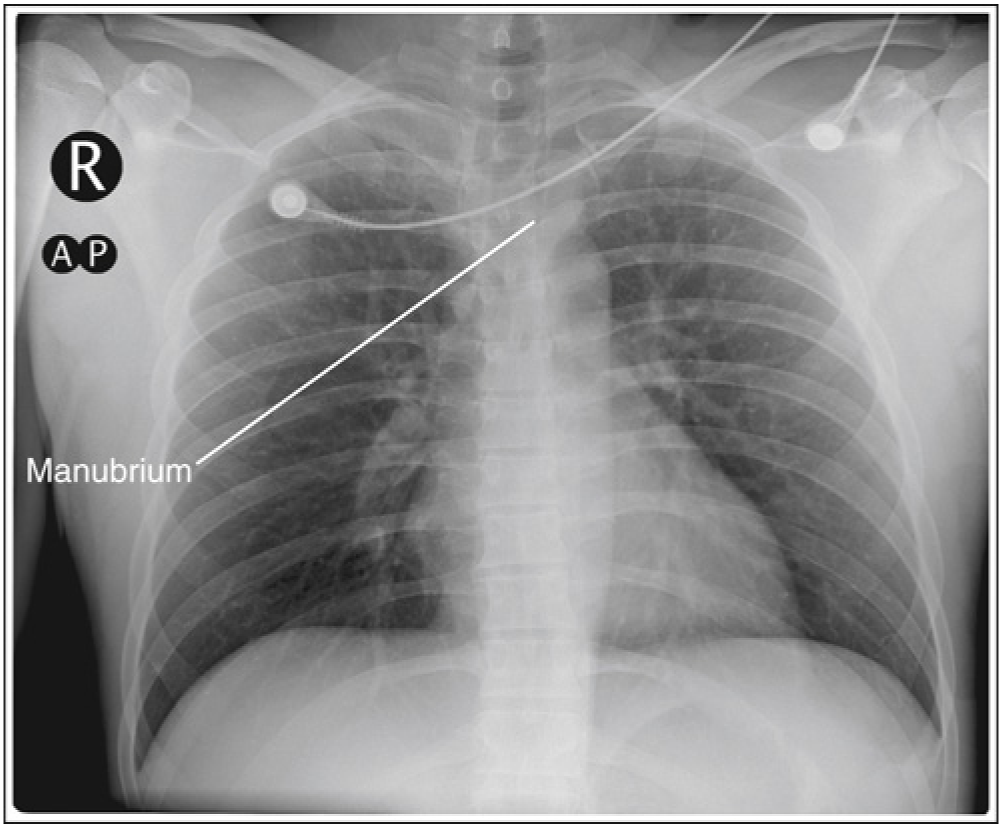


FIGURE 3.60 AP chest taken with CR angled too cephalically.

Positioning for the Supine Patient

For the supine AP chest projection, the patient's kyphotic thoracic vertebrae are forced to extend slightly, straightening because of the body weight and gravitational pull on them. This straightening causes the anterior thoracic cage, with the manubrium and clavicles, to move superiorly and results in the projection demonstrating less than 1 inch (2.5 cm) of apical lung field superior to the clavicles (**Fig. 3.63**). Placing a 5-degree caudal angle on the CR can offset this.

Clavicle

When the patient's condition allows, position the lateral ends of the clavicles on the same horizontal plane as the medial ends by depressing the shoulders. Accurate positioning of the clavicles lowers the lateral ends of the clavicles, positioning the middle and lateral clavicles away from the apical chest region and improving visualization of the apical lung field. If the patient is unable to depress his or her shoulders, the middle and lateral ends of the clavicles will be seen in the apical chest region (**Fig. 3.64**).

Scapulae

To position most of the scapulae outside the lung field, place the back of the hands low enough on the hips so they are not in the collimated field, and rotate the elbows and shoulders anteriorly. Most patients who require mobile or supine chest projections are incapable of positioning their arms in this manner, resulting in a projection with the scapulae positioned in the lung field. In such a situation, abduct the arms until they are placed outside the imaging field to prevent unnecessary exposure to them (see **Fig. 3.64**).

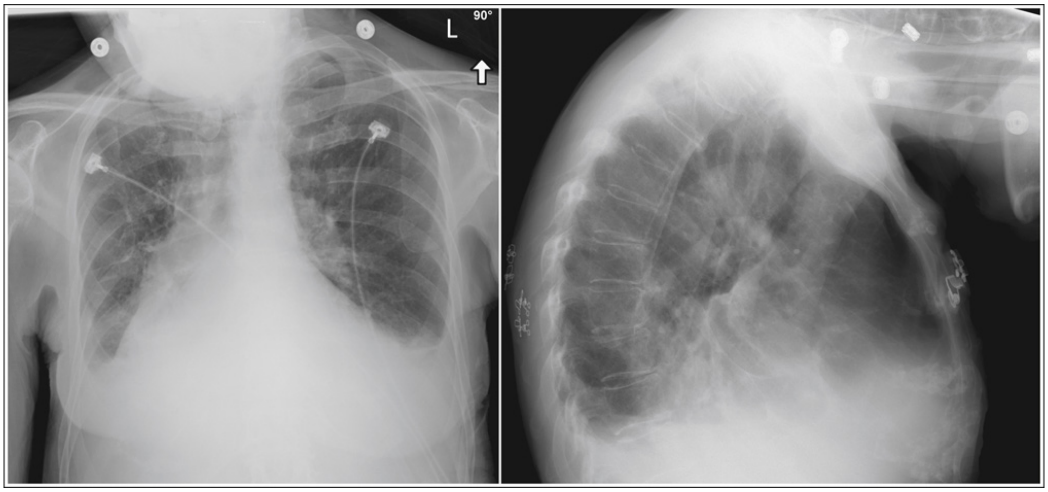


FIGURE 3.61 AP and lateral chest on patient with spinal kyphosis. AP was taken with midcoronal plane parallel with IR and CR perpendicular. Lateral shows why the chin obscures apices on AP.

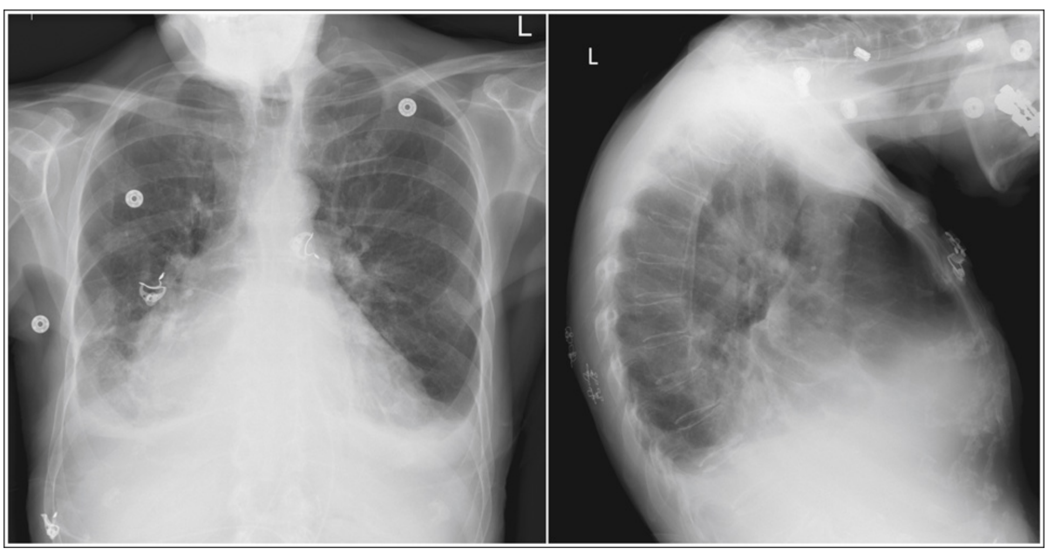


FIGURE 3.62 AP and lateral chest on patient with spinal kyphosis. AP was taken with midcoronal plane tilted with IR and CR perpendicular. Lateral shows how this moves chin superior to apices.

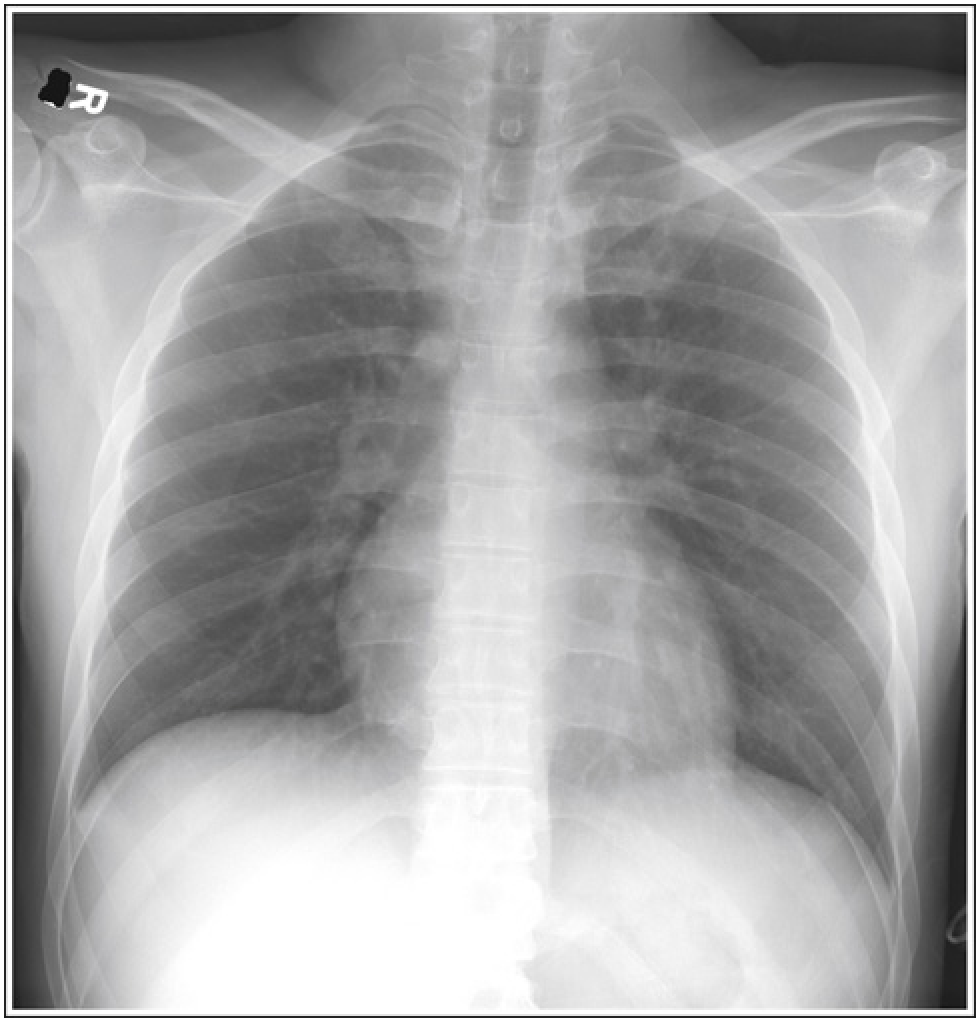


FIGURE 3.63 Supine AP chest projection with accurate positioning.

Lung Aeration

In a supine or seated patient, the diaphragm is unable to shift to its lowest position because the abdominal organs are compressed and push against the diaphragm. As a result, adequate lung aeration for an AP chest has resulted when at least nine posterior ribs are visualized above the diaphragm. If the diaphragm is superior to the ninth posterior ribs, full lung expansion has not been obtained (**Fig. 3.65**).

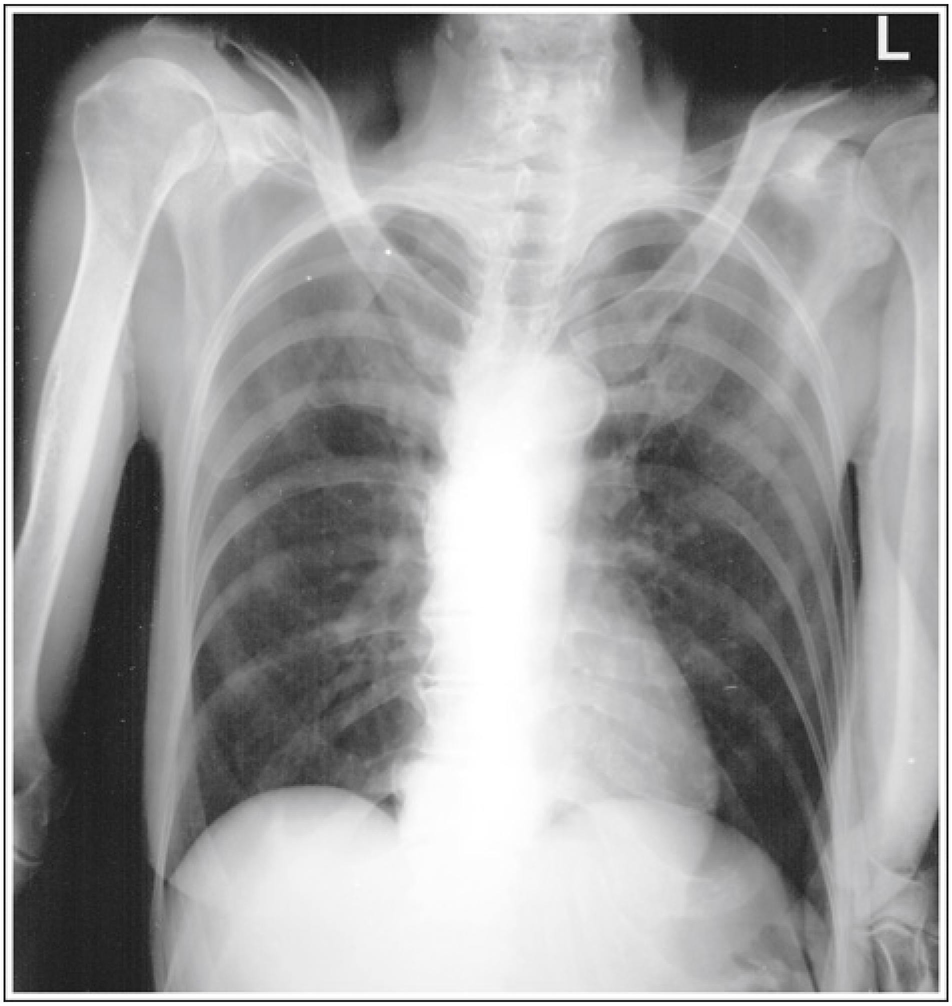


FIGURE 3.64 Supine AP chest with elevated shoulders and arms in the exposure field.

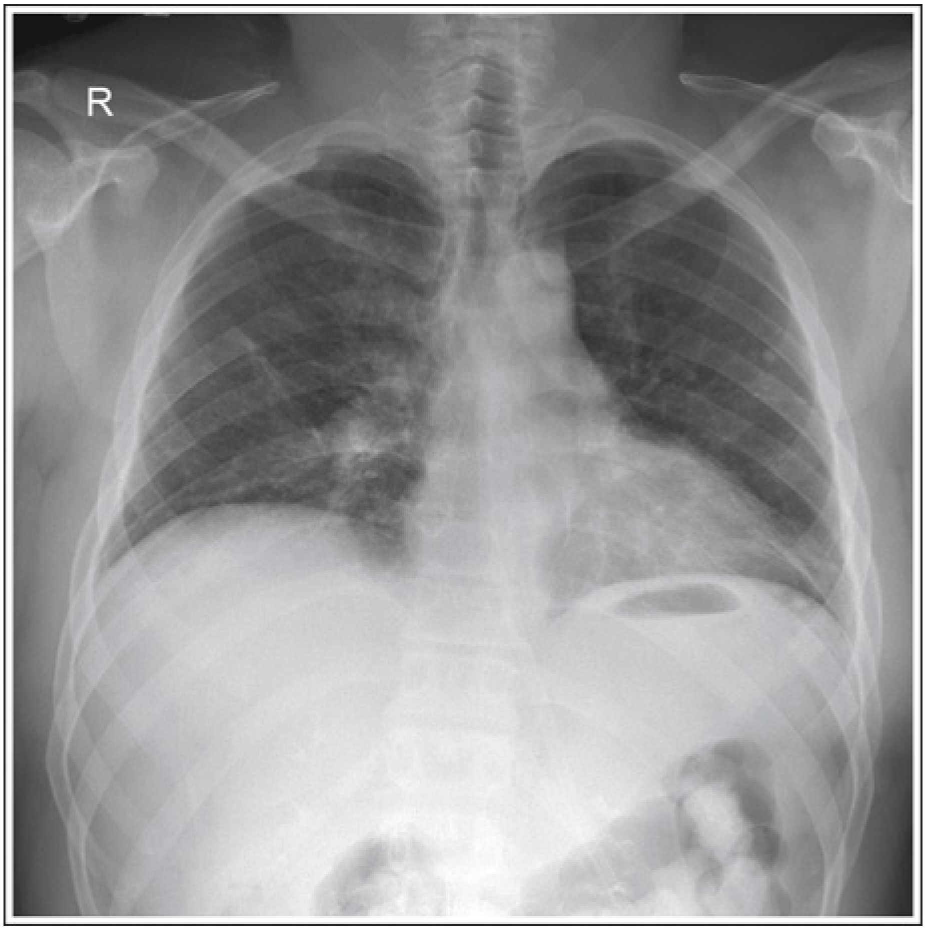


FIGURE 3.65 AP chest without full lung aeration.

AP Chest (Portable) Analysis Practice

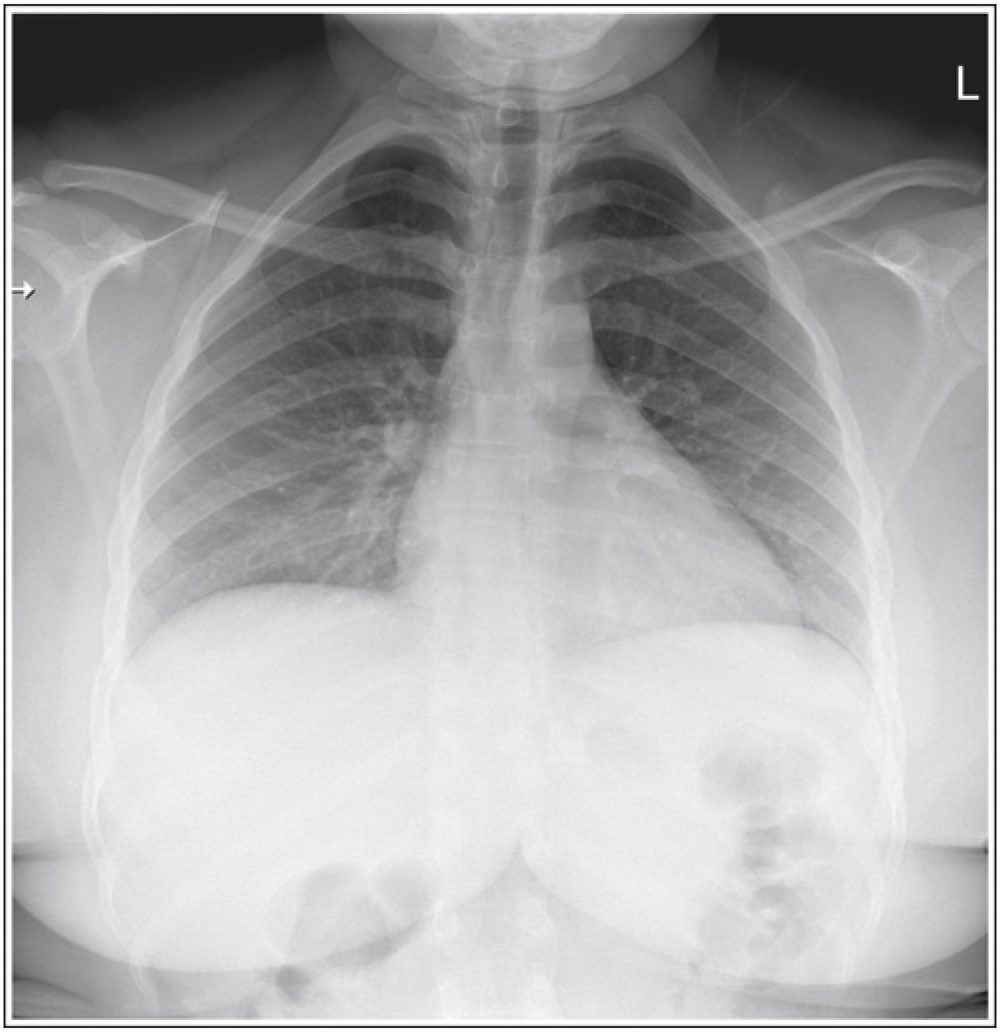


IMAGE 3.7

Analysis

The diaphragm is superior to the ninth posterior ribs. The projection was not obtained after full lung aeration. More than 1 inch (2.5 cm) of the apices is seen above the clavicles, and the manubrium superimposes the fifth thoracic vertebrae. The CR was angled too caudally.

Correction

If the patient's condition allows, take the exposure after coaxing the patient into a deeper inspiration or at the point at which the ventilator indicates the greatest lung expansion. Adjust the CR cephalically until it is aligned perpendicular to the midcoronal plane.

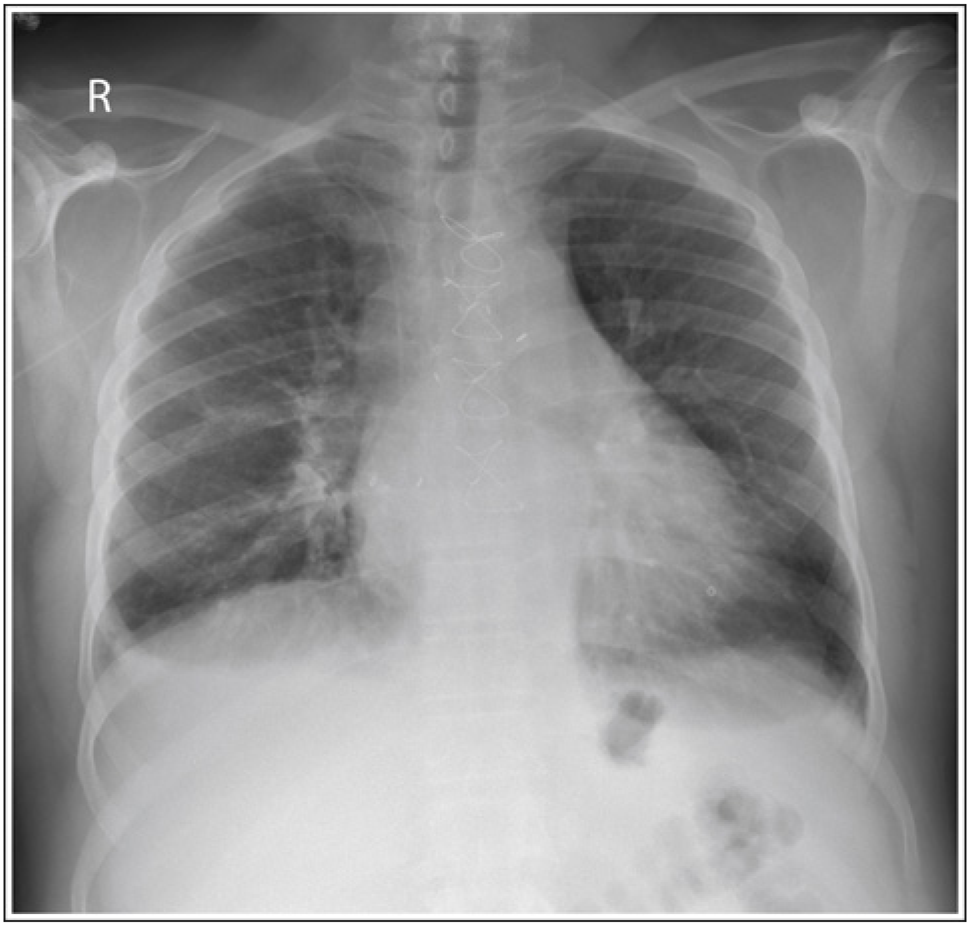


IMAGE 3.8

Analysis

The manubrium is superimposed over the third thoracic vertebra, and less than 1 inch (2.5 cm) of apical lung field is visible above the clavicles. The posterior ribs demonstrate a horizontal contour. The CR was angled cephalically.

Correction

Adjust the CR angulation caudally until it is aligned perpendicular to the midcoronal plane.

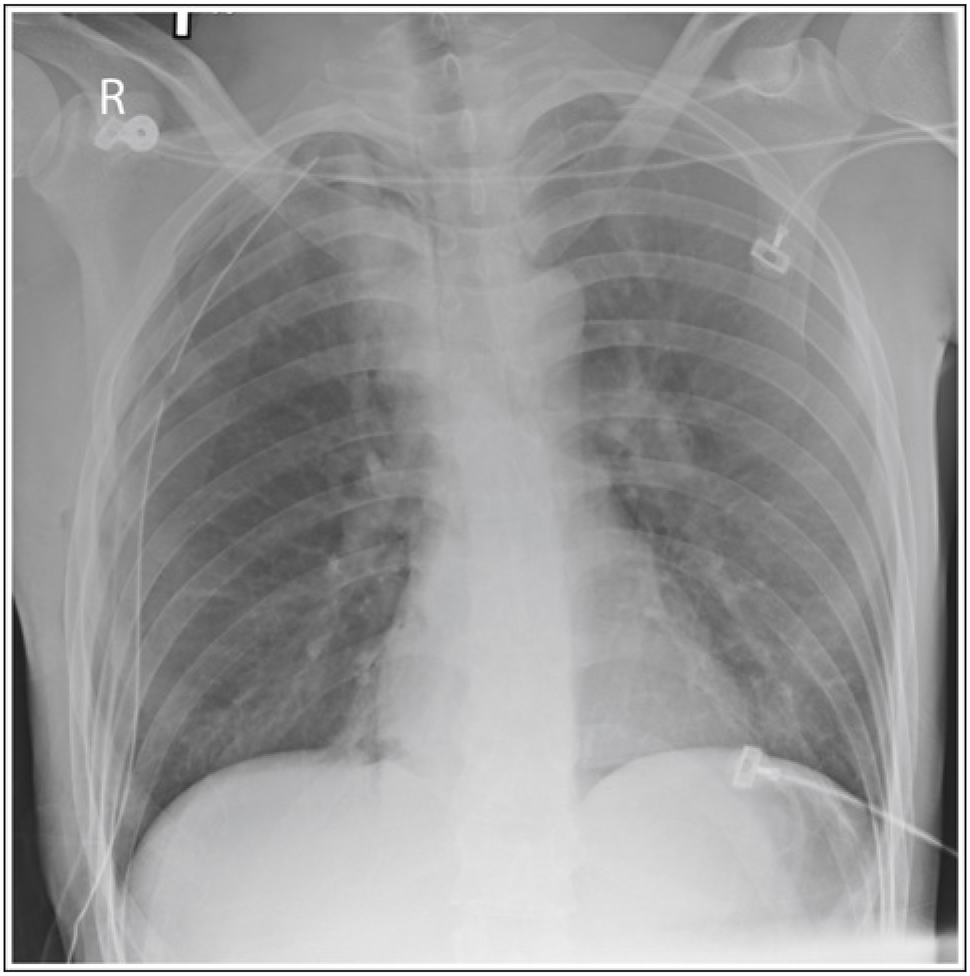


IMAGE 3.9

Analysis

The manubrium is inferior to the fourth thoracic vertebra, more than 1 inch (2.5 cm) of lung apices is demonstrated superior to the clavicles, and the posterior rib contour is vertical. The CR was angled too caudally. The

lateral clavicular ends are superior to the medial clavicular ends. The shoulders were elevated.

Correction

Adjust the CR angulation cephalically until it is aligned perpendicular to the midcoronal plane and depress the shoulders.

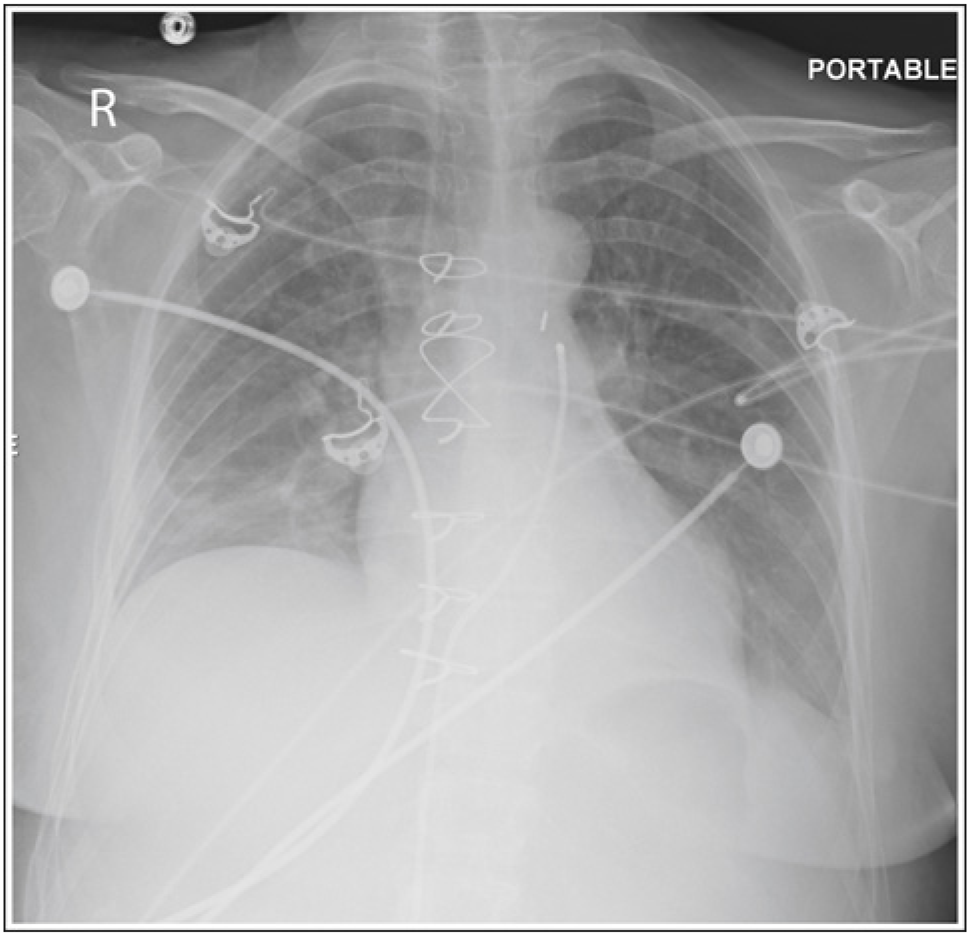


IMAGE 3.10

Analysis

The right sternal clavicular end is demonstrated farther from the vertebral column than the left. The right side of the patient and IR were placed closer

to the bed and farther from the collimator's face than the left side (CR angled toward the right side). The manubrium is inferior to the fourth thoracic vertebra, more than 1 inch (2.5 cm) of lung apices is demonstrated superior to the clavicles, and the posterior rib contour is vertical. The CR was angled too caudally. There are numerous external artifacts covering the lungs.

Correction

Elevate the right side of the patient and IR or adjust the CR angle toward the left side of the patient until the collimator's face is parallel with the midcoronal plane and IR. Adjust the CR angulation cephalically until it is aligned perpendicular to the midcoronal plane. Shift the artifacts so they are not covering the lung field where possible.

Chest: AP or PA Projection (Right or Left Lateral Decubitus Position)

See **Table 3.6** and Figs. **3.66** and **3.67**.

Cart Pad Artifact

Elevating the patient on a radiolucent sponge or on a hard surface, such as a cardiac board, prevents the chest from sinking into the imaging table or cart pad. When the thorax is allowed to sink into the pad, artifact lines are seen superimposed over the lateral lung field of the side placed against the pad (**Fig. 3.68**). Because fluid in the pleural cavity gravitates to the lowest level, superimposition of the cart pad and the lower lung field may obscure fluid that has settled in the lowest position (**Fig. 3.69**).

Positioning to Demonstrate Air or Fluid Levels

The lateral decubitus position is primarily used to confirm the presences of pneumothorax or pleural effusion in the pleural cavity (**Table 3.7**).

Using the Cervical Vertebrae to Distinguish Between the AP and PA Projections

Whether the lateral decubitus chest is obtained in the AP or PA projection is not a concern, because the projection is not obtained to evaluate the heart size. But to be able to determine how to improve a rotated projection, it is necessary to be able to tell the difference. To determine whether a chest projection was taken in an AP or PA projection, analyze the appearance of the sixth and seventh cervical vertebrae and the first thoracic vertebra. In the AP projection these vertebral bodies and their intervertebral disk spaces are demonstrated without distortion (**Fig. 3.70**). In the PA projection, the vertebral bodies are distorted, the intervertebral disk spaces are closed, and the spinous processes and laminae of these three vertebrae are well demonstrated (**Fig. 3.71**). The reason for these variations is related to the divergence of the x-ray beam used to image these three vertebrae and the anterior convexity of the cervical and upper thoracic vertebrae.

Chest Rotation

On a rotated AP projection, the sternal clavicular end that demonstrates the least vertebral column superimposition, and the side on which the posterior ribs demonstrate the greatest length, is the side of the chest positioned closer to the IR (Figs. **3.72** and **3.73**). In the AP projection it is easier for the patient to maintain a nonrotated projection, because the knees can be flexed and a pillow placed between them to stabilize the patient. The opposite is true for a PA projection. For this projection, the sternal clavicular end that demonstrates the least amount of the vertebral column and the posterior ribs

that demonstrate the greatest length represent the side of the chest positioned farther from the IR.

Anterior Midcoronal Plane Tilting

If an AP or PA decubitus chest projection is taken, with the superior midcoronal plane tilted anteriorly, the manubrium will move inferior to the fourth thoracic vertebra (**Fig. 3.74**).

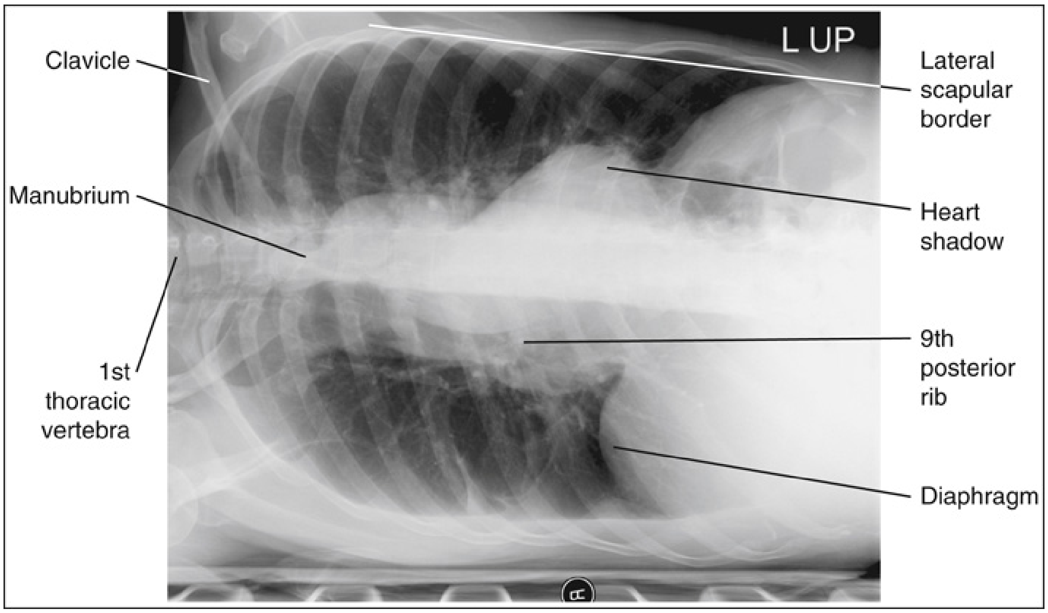


FIGURE 3.66 AP (right lateral decubitus) chest projection with accurate positioning.

FIGURE 3.67 Proper patient positioning for AP (left lateral decubitus) chest projection.

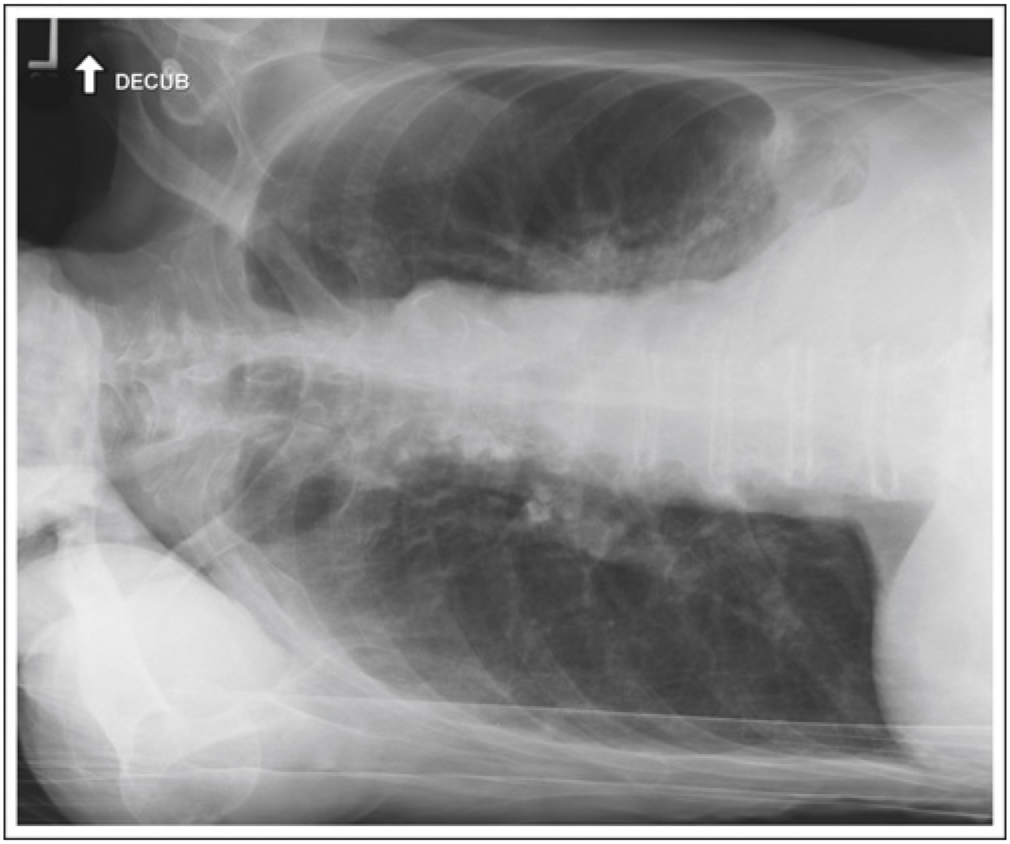


FIGURE 3.68 PA (right lateral decubitus) chest projection demonstrating cart artifact and the right arm not elevated above head.

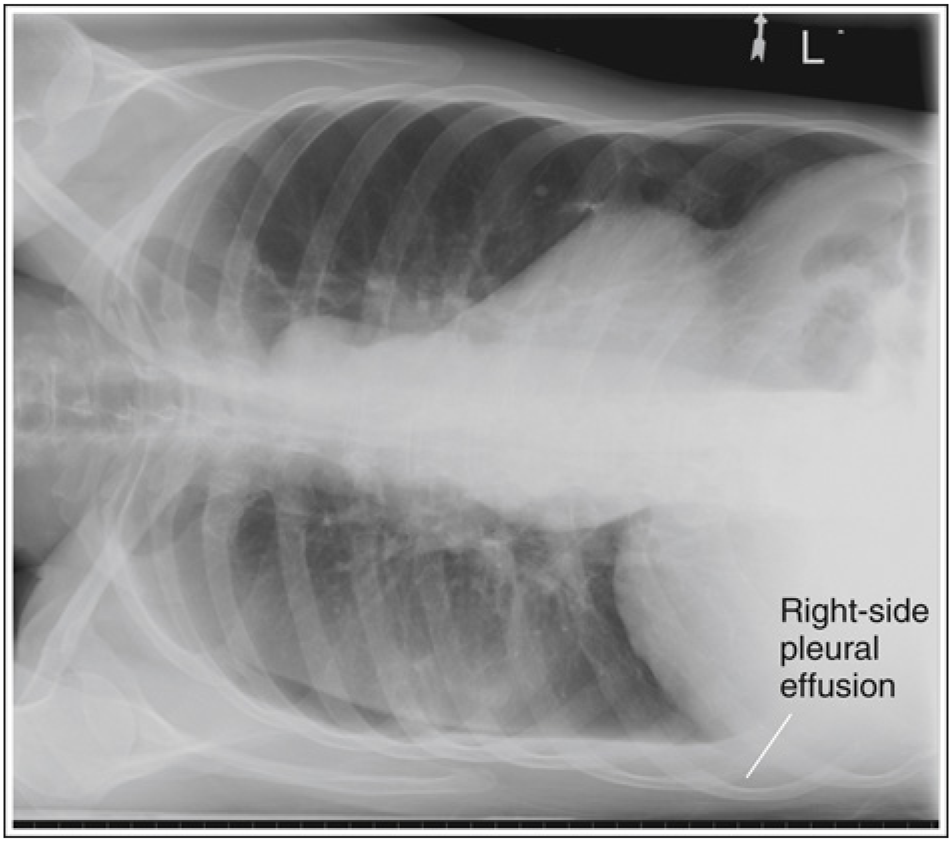


FIGURE 3.69 AP (right lateral decubitus) chest demonstrating right-sided pleural effusion.

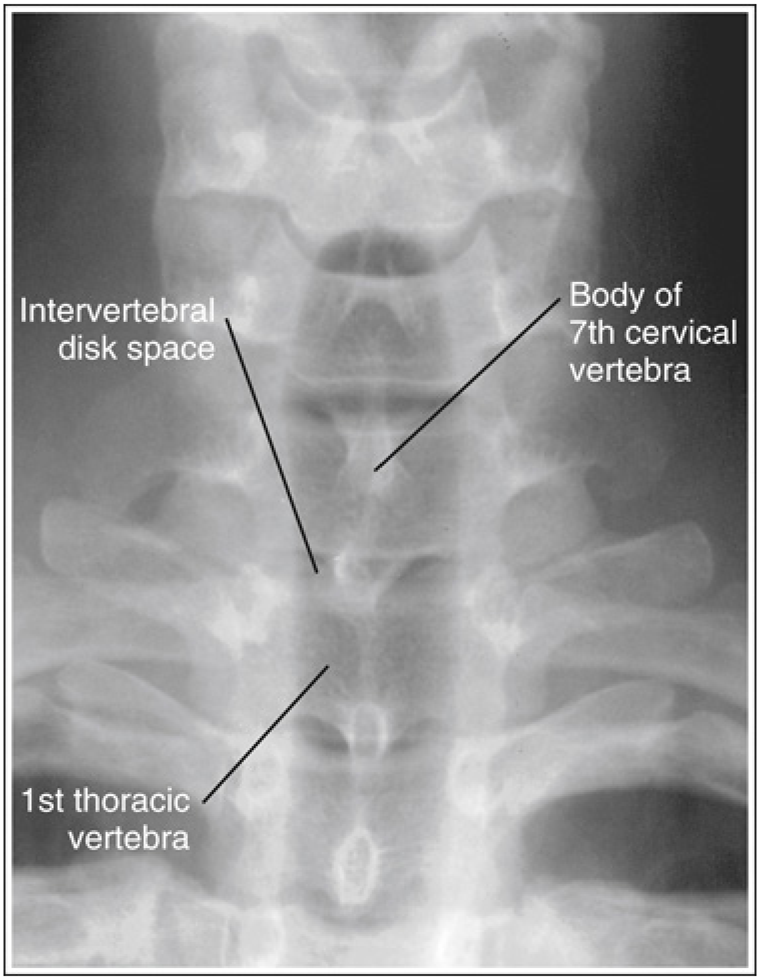


FIGURE 3.70 AP projection of cervical vertebrae.

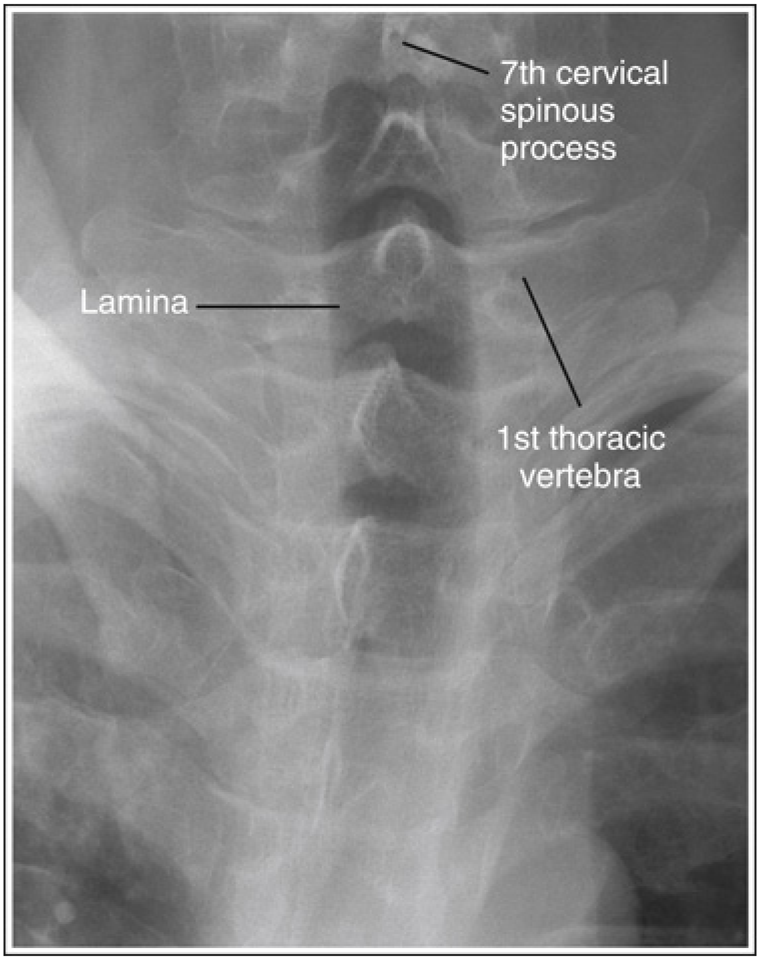


FIGURE 3.71 PA projection of cervical vertebrae.

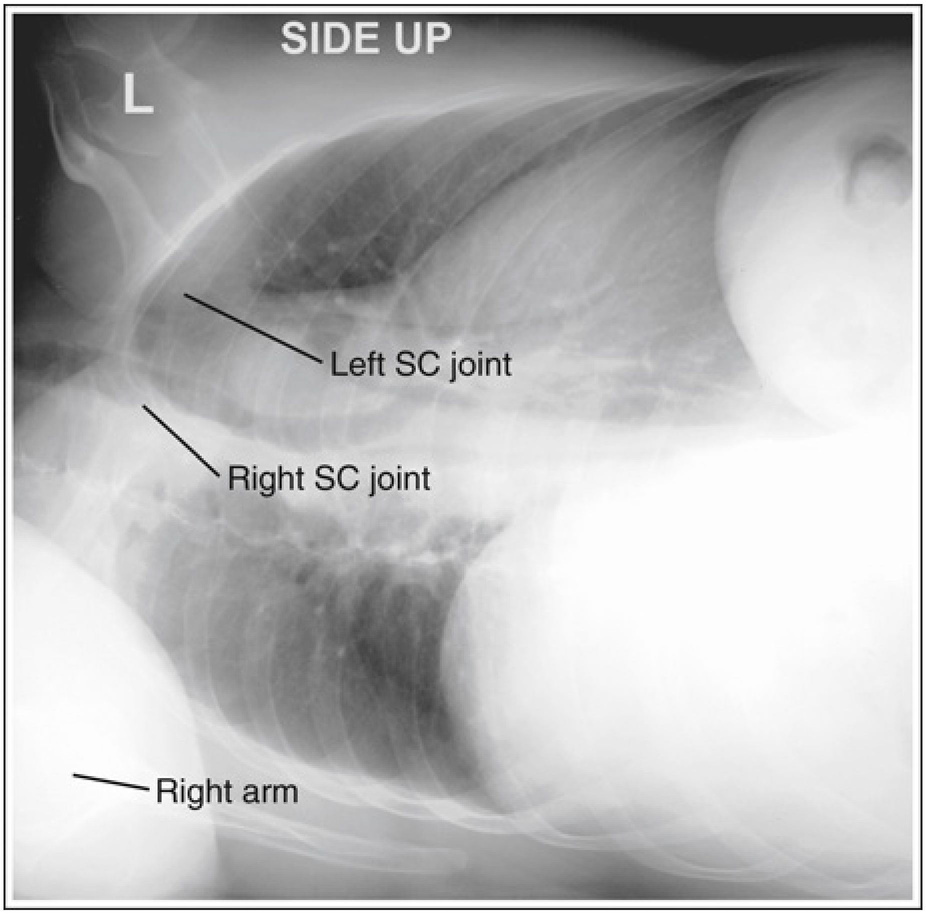


FIGURE 3.72 AP (right lateral decubitus) chest with left side rotated closer to IR than right side.

TABLE 3.6

CR, Central ray; *CW*, crosswise; *IR*, image receptor; *LW*, lengthwise.

TABLE 3.7

Determining Side to Place Downward for AP/PA Decubitus Chest Positioning

Pneumothorax	To best demonstrate the presence of a pneumothorax, position the affected side of the thorax away from the imaging table or cart so that the air rises to the highest level in the pleural cavity. If the affected side were placed against the imaging table or cart, the air might be obscured by the mediastinal structures (**Fig. 3.68**).
Pleural effusion	To best demonstrate pleural effusion, position the affected side against the imaging table or cart. This positioning allows the fluid to gravitate to the lowest level of the pleural cavity, away from the mediastinal structures (**Fig. 3.69**).

Posterior Midcoronal Plane Tilting

If an AP or PA projection is taken with the superior midcoronal plane tilted posteriorly (backward), the manubrium will move superior to the fourth thoracic vertebra (**Fig. 3.75**).

Scapulae

The lateral borders of the scapulae are drawn away from the lung field when the arms are positioned above the head. This positioning also draws the lateral ends of the clavicles superiorly (see **Fig. 3.69**). If the arms are

not positioned in this manner, the arms and the lateral borders of the scapulae are demonstrated within the upper lung field (see **Fig. 3.68**).

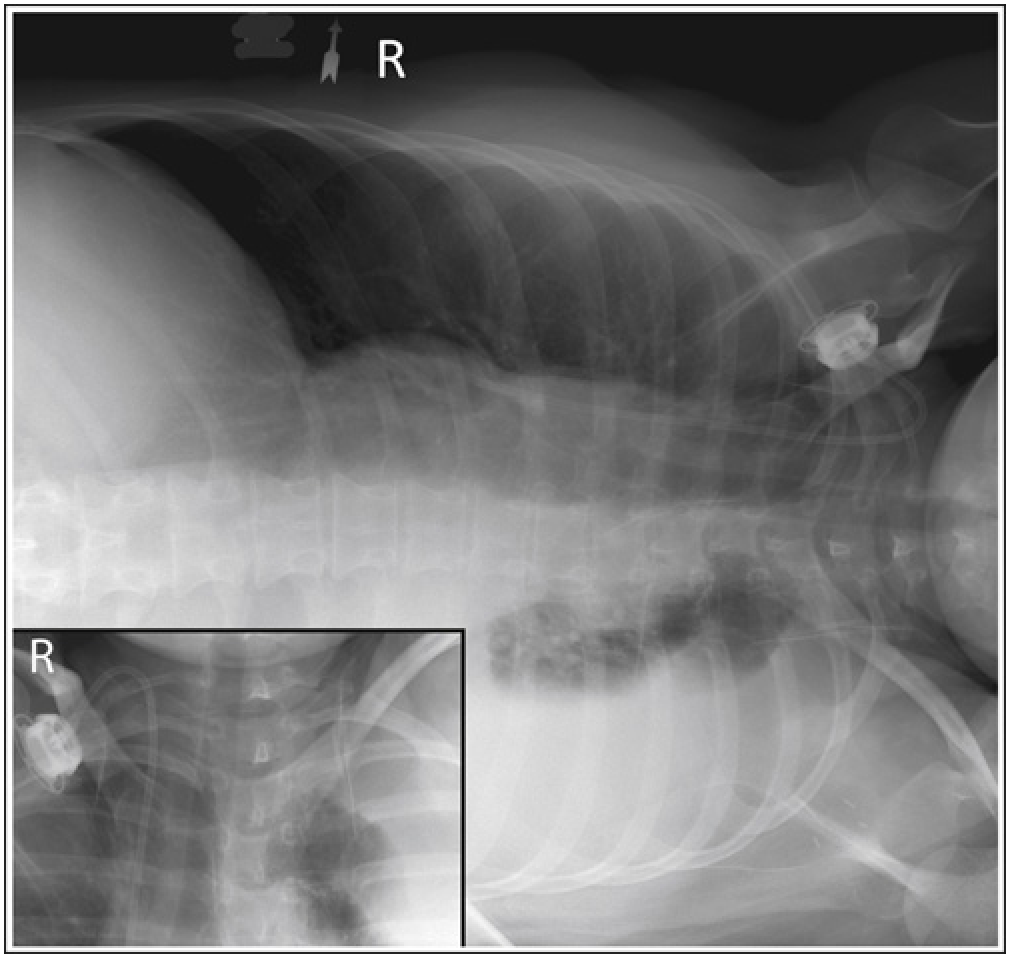


FIGURE 3.73 AP (left lateral decubitus) chest with right side rotated closer to IR than left side.

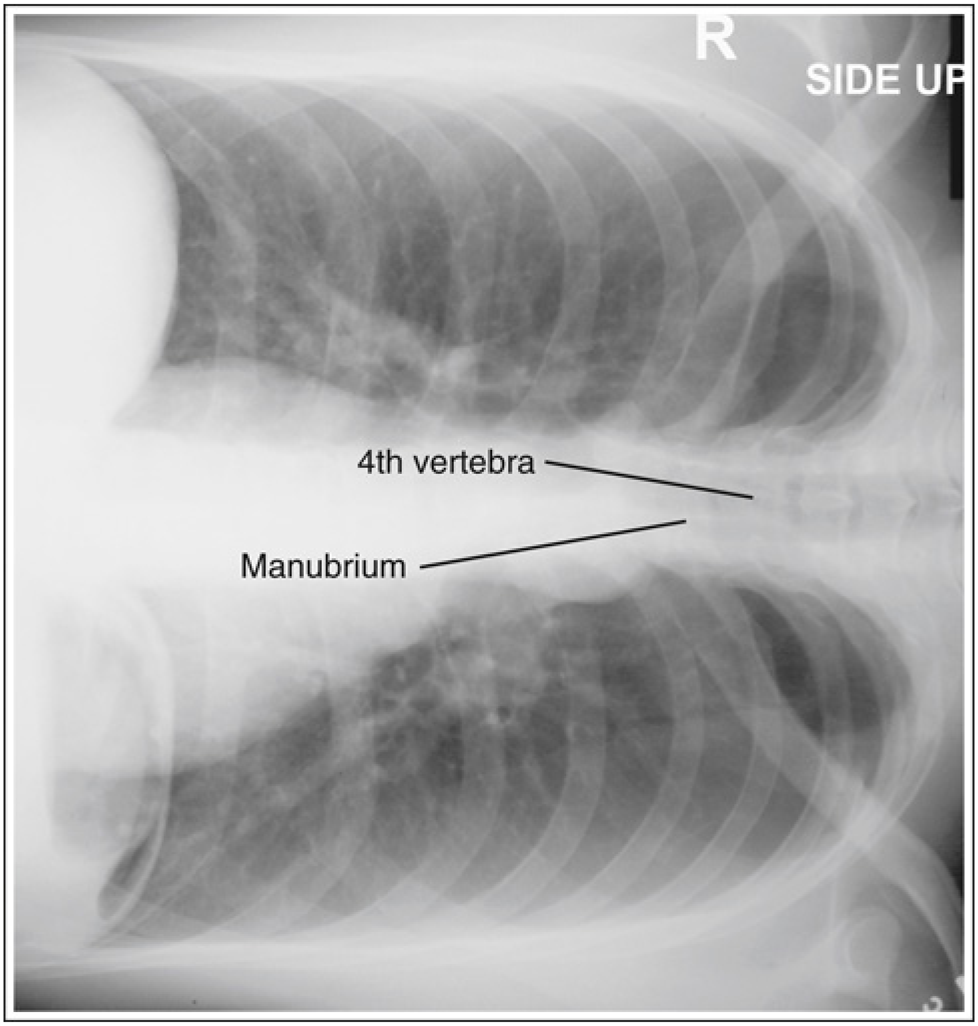


FIGURE 3.74 AP (left lateral decubitus) chest with superior midcoronal plane tilted away from IR.

Lung Aeration

In the recumbent position, the diaphragm is unable to shift to its lowest position because of pressure from the peritoneal cavity. As a result, adequate lung aeration for an AP/PA (lateral decubitus) chest has resulted when at least nine posterior ribs are demonstrated above the diaphragm. If fewer than nine are demonstrated, lung expansion has not been accomplished (**Fig. 3.76**).

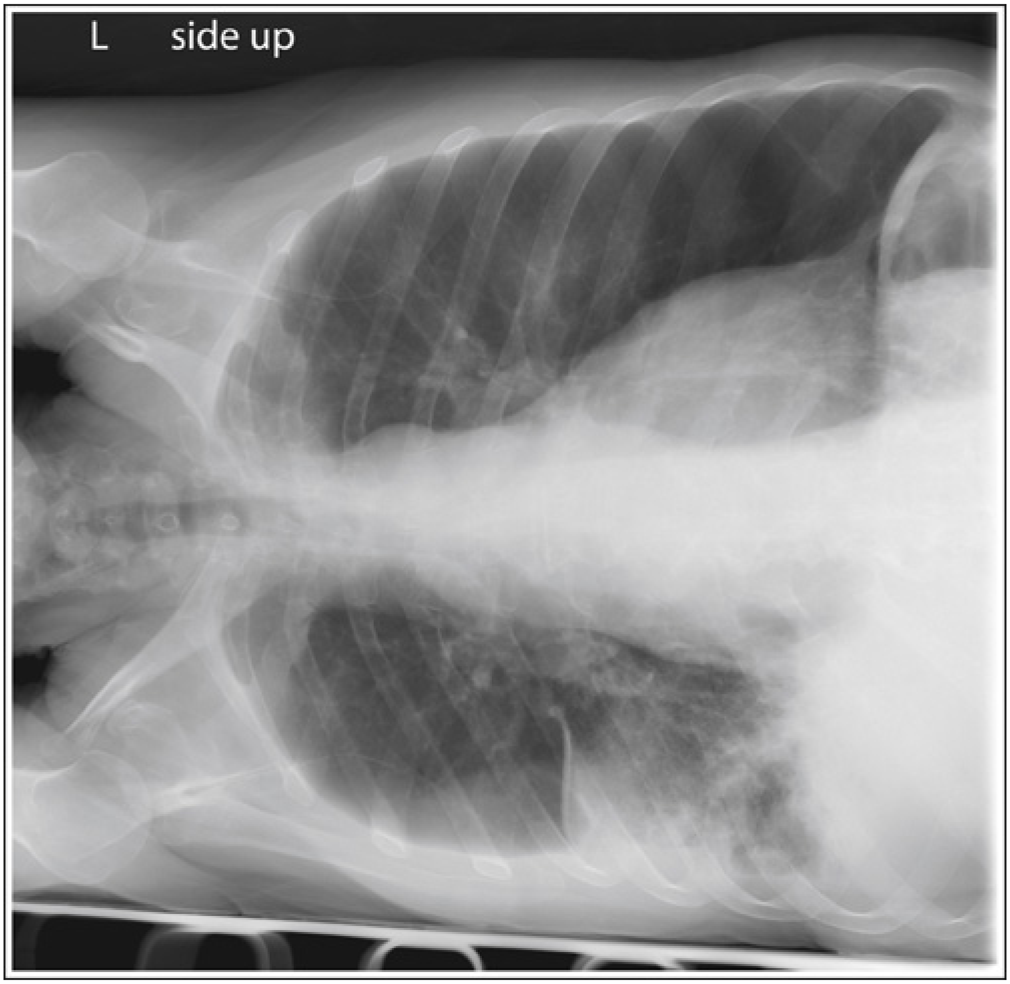


FIGURE 3.75 AP (right lateral decubitus) chest demonstrating accurate arm and scapulae positioning, with superior midcoronal plane tilted toward the IR.

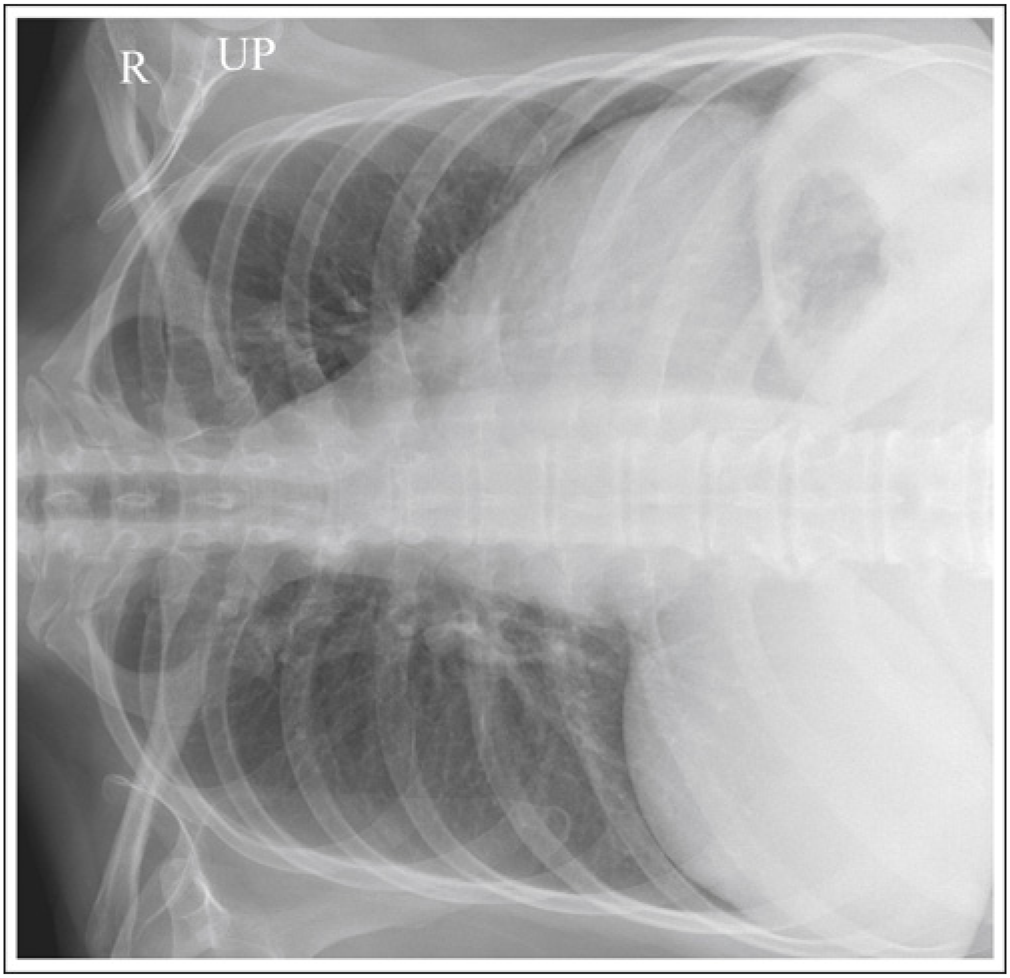


FIGURE 3.76 AP (left lateral decubitus) chest without full lung aeration. Less than nine posterior ribs.

Decubitus Chest Analysis Practice

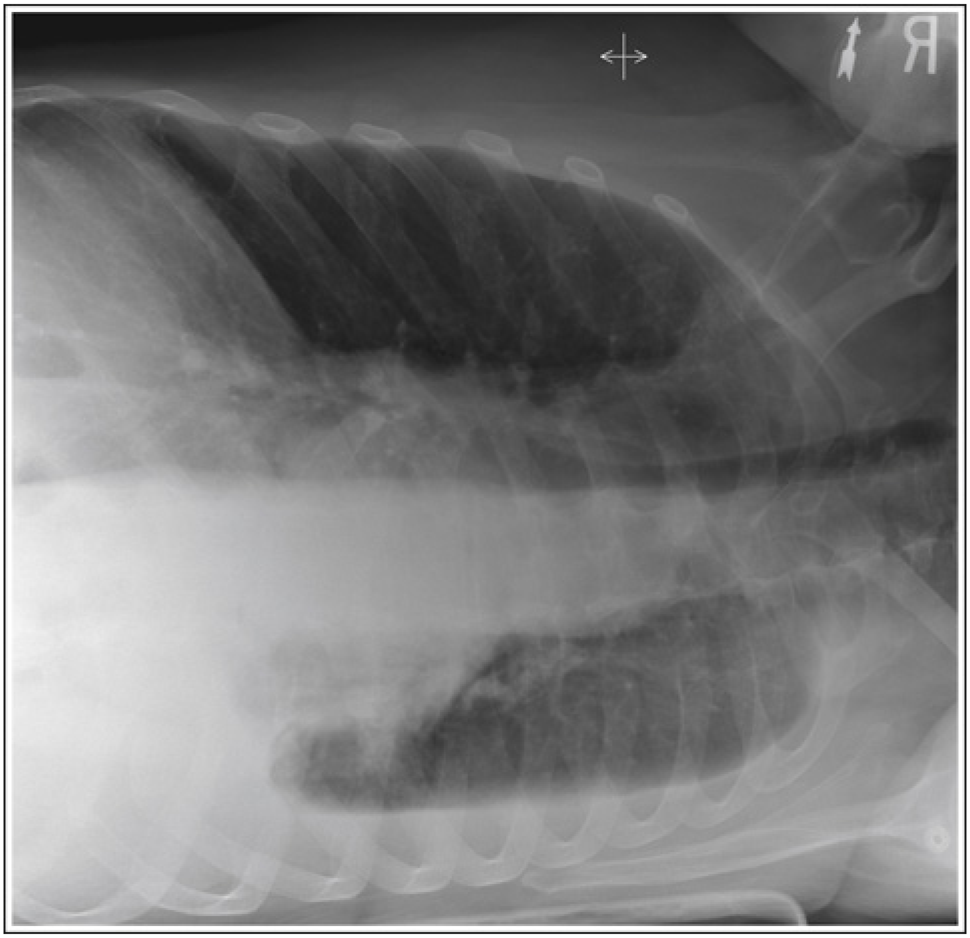


IMAGE 3.11

PA (LEFT LATERAL DECUBITUS) PROJECTION.

Analysis

The right sternal clavicular end is situated farther from the vertebral column than the left, and the posterior ribs on the right side demonstrate the greater length. The right thorax was rotated away from the IR.

Correction

Rotate the right side of the thorax toward the IR until the midcoronal plane is aligned parallel with the IR.

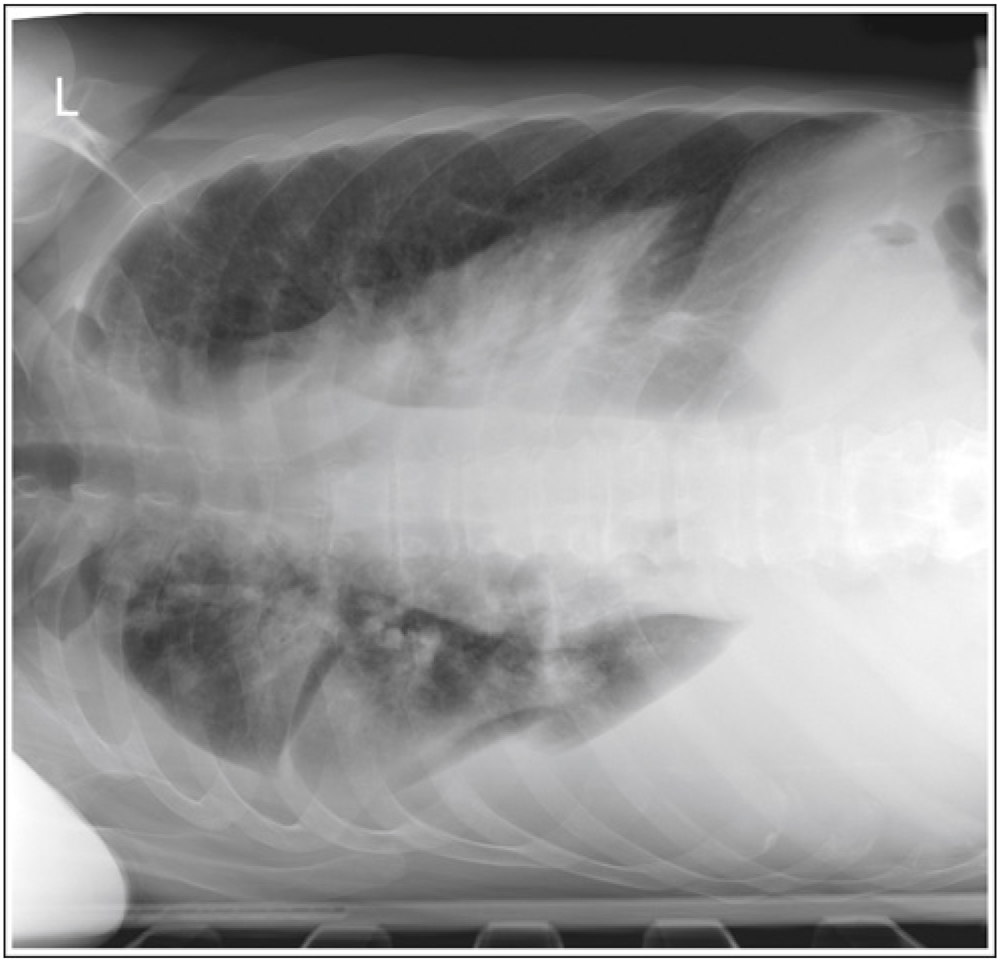


IMAGE 3.12

AP (RIGHT LATERAL DECUBITUS) PROJECTION.

Analysis

The manubrium is situated above the level of the fourth thoracic vertebra. The upper midcoronal plane was tilted posteriorly. The right arm was not elevated.

Correction

Move the upper midcoronal plane anteriorly until the entire midcoronal plane is aligned parallel with the IR, and elevate the right arm.

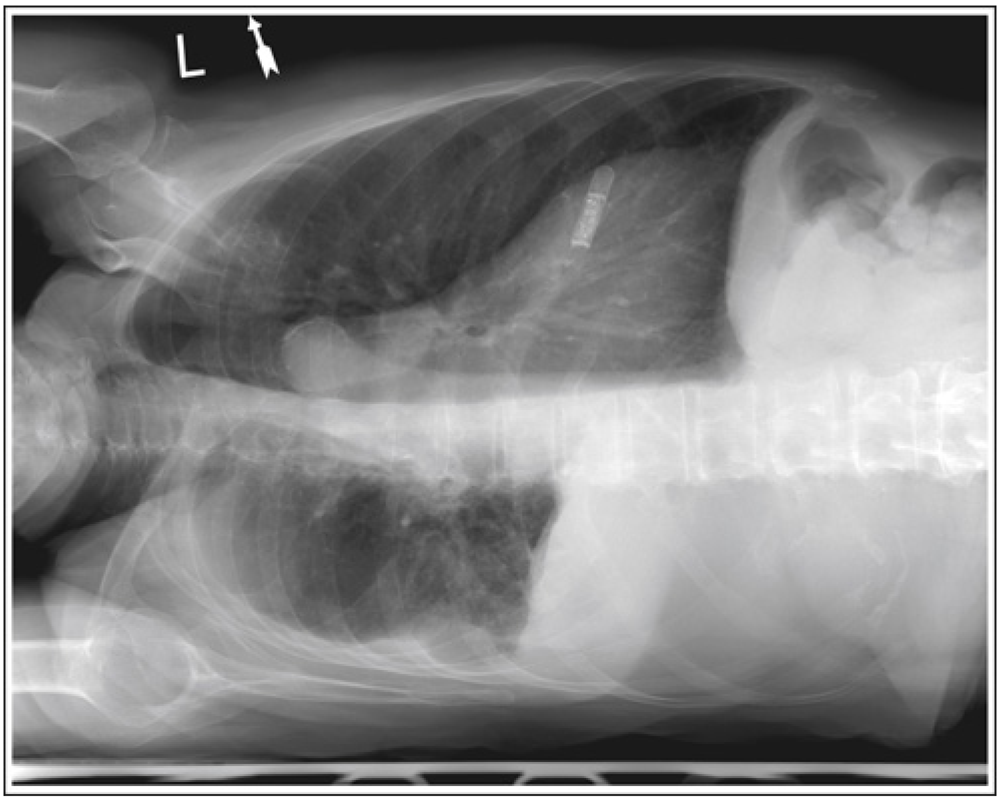


IMAGE 3.13

AP (RIGHT LATERAL DECUBITUS) PROJECTION.

Analysis

The left sternal clavicular end is situated farther from the vertebral column than the right, and the posterior ribs on the left side demonstrate the greater length. The left thorax was rotated toward the IR.

Correction

Rotate the left side of the thorax away from the IR until the midcoronal plane is aligned parallel with the IR.

Chest: AP Axial Projection (Lordotic Position)

See **Table 3.8**, and Figs. **3.77** to **3.79**.

Exam Indication

Overlying soft tissues, clavicles, and upper ribs often obscure the apical lung markings on a PA projection of the chest. The anterior ends of the first ribs may also project a suspicious-looking shadow in the apices. The AP axial projection is taken to demonstrate areas of the apical lungs obscured on the PA projection and to provide a different anatomic perspective that can be used to evaluate suspicious areas.

Determining the Degree of CR Angulation for Method 2

In method 2 the patient is unable to arch the back enough to bring the midcoronal plane at a 45-degree angle with the IR, so it requires the CR to be angled cephalically to obtain the needed 45-degree angle between the midcoronal plane and CR. The required angulation is determined by estimating the degree of midcoronal plane and IR angle, and subtracting that angle from 45 degrees. For example, if the midcoronal plane is placed at a 30-degree angle with the IR, the needed CR angle would be 15 degrees

cephalically (**Fig. 3.80**). If the procedure is taken to demonstrate interlobar effusion, the CR should not be angled. Instead, a modified projection with the patient leaning 15 to 20 degrees is recommended.

TABLE 3.8

CR, Central ray; *IR*, image receptor; *LW*, lengthwise.

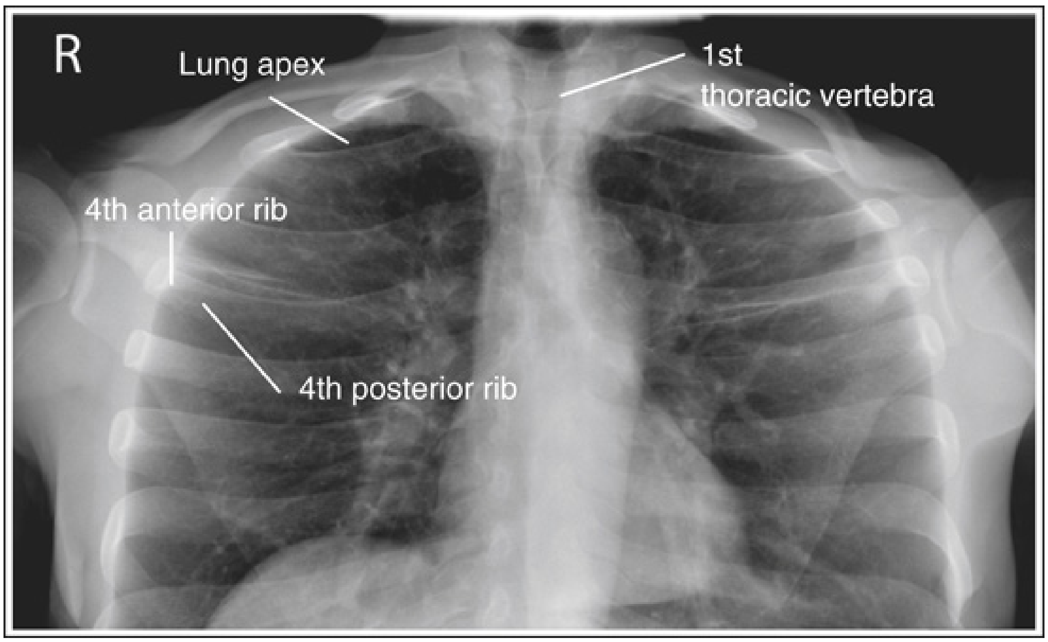


FIGURE 3.77 AP axial (lordotic) chest projection with accurate positioning.

FIGURE 3.78 Proper patient positioning for AP axial (lordotic) chest projection—Midcoronal plane at 45 degrees with no CR angle.

FIGURE 3.79 Proper patient positioning for AP axial (lordotic) chest projection—Midcoronal plane parallel with IR with CR angled 45 degrees.

Insufficient Back Extension or Cephalic CR Angulation

Insufficient back extension or degree of CR angulation is identified on an AP axial chest when the clavicles are not adequately projected superior to the lung apices and when the anterior and posterior ribs are not superimposed. If the back is not arched enough or when more cephalic CR

angulation is needed, the clavicles superimpose the lung apices, and the anterior ribs are demonstrated inferior to their corresponding posterior rib (**Fig. 3.81**).

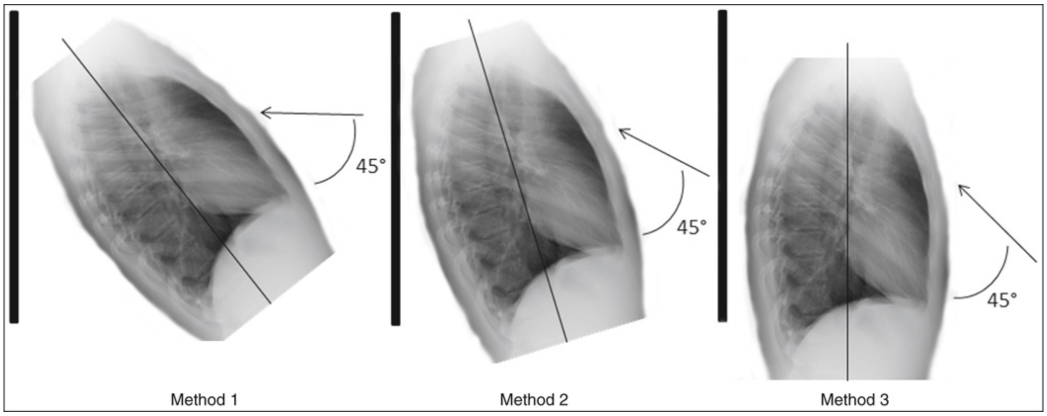


FIGURE 3.80 Three methods of determining the CR angulation to use for the AP axial (lordotic) chest projection.

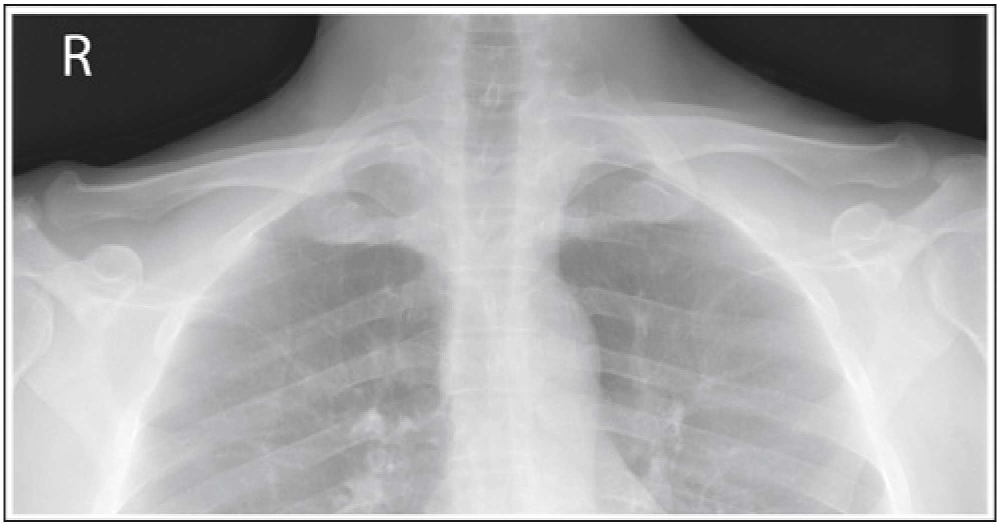


FIGURE 3.81 AP axial (lordotic) chest taken with less than a 45-degree midcoronal plane to CR angulation.

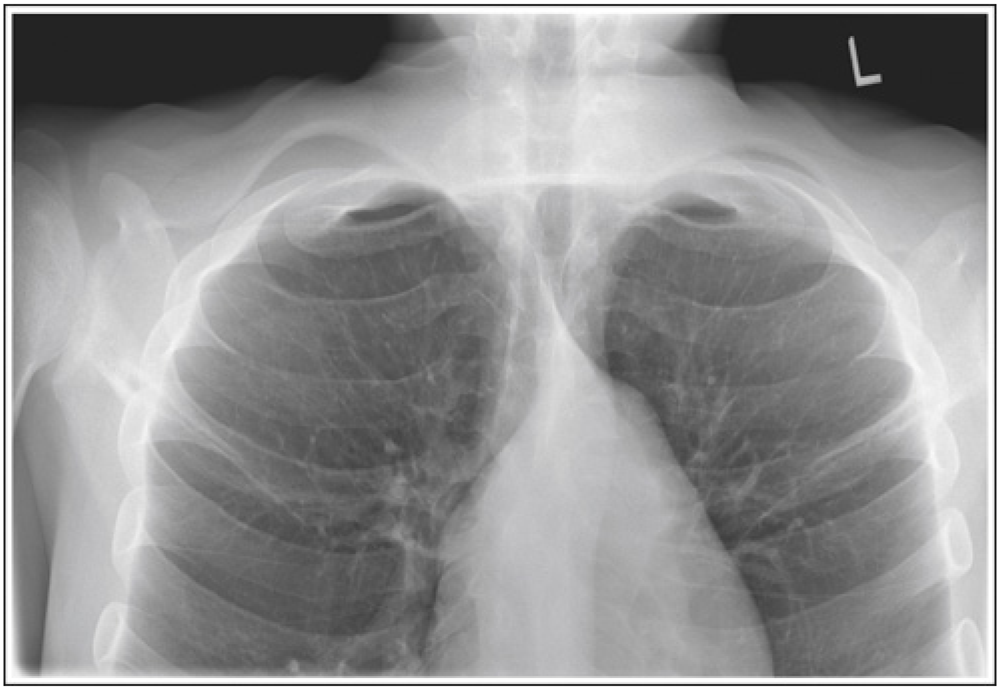


FIGURE 3.82 AP axial (lordotic) chest taken with more than a 45-degree midcoronal plane to CR angulation.

Excessive Back Extension or Cephalic CR Angulation

If a projection is obtained that demonstrates the lung fields with so much foreshortening that the apices are obscured and the posterior ribs are superimposed and cannot be distinguished, the back was arched too much or the cephalic CR angle was too extreme (**Fig. 3.82**).

Chest Rotation

Chest rotation can be identified on an AP axial projection by evaluating the distance between the vertebral column and the sternal clavicular ends. When the distances between the sternal clavicular ends and the vertebral column are unequal, the clavicular end that is superimposed over the

greatest amount of the vertebral column is the side of the chest that was positioned farthest from the IR.

AP Lordotic Chest Analysis Practice

IMAGE 3.14

Analysis

The lung fields demonstrate excessive foreshortening, and the individual ribs cannot be identified.

Correction

If the back was arched to obtain this projection, decrease the amount of arch until the midcoronal plane and CR form a 45-degree angle. If this examination was obtained with a cephalic CR angulation, decrease the

degree of angulation until the midcoronal plane and CR form a 45-degree angle.

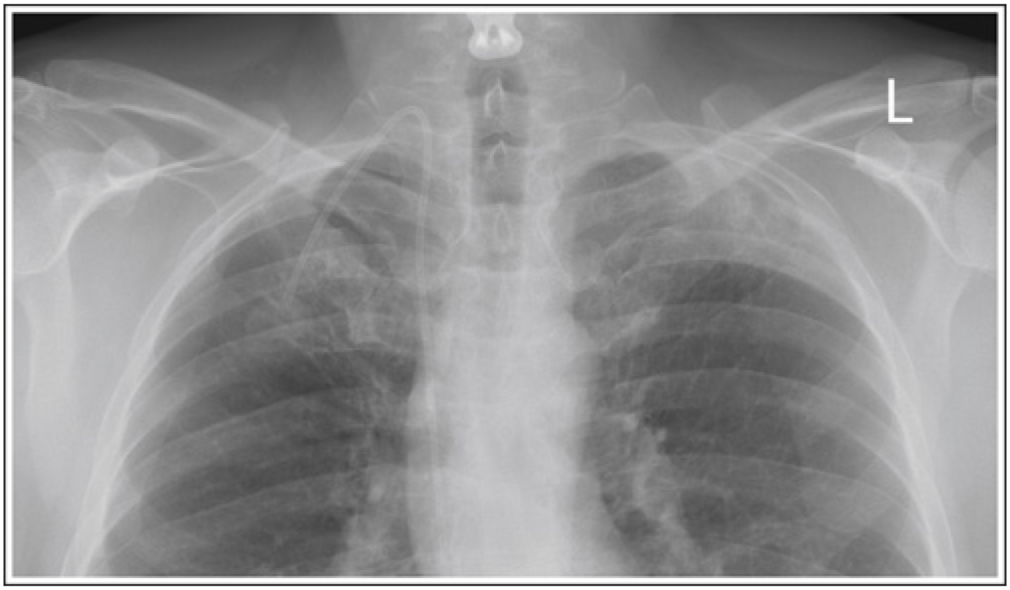


IMAGE 3.15

Analysis

The clavicles are superimposed over the lung apices, and the anterior ribs are demonstrated inferior to their corresponding posterior rib.

Correction

If the patient is able, increase the amount of back arch until the midcoronal plane and CR form a 45-degree angle. If the patient is unable to increase the back arch, increase the degree of the right sternal clavicular end a 45-degree angle with the midcoronal plane.

PEDIATRIC CHEST

Neonate and Infant Chest: AP Projection

See **Table 3.9** and Figs. **3.83** and **3.84**.

Chest Rotation: Side-to-Side CR Alignment

In the AP neonate and infant, chest projection chest rotation is caused by poor IR balance, poor side-to-side (lateral-to-lateral) CR alignment, and head rotation. To prevent chest rotation, align the transverse axis of the IR and midcoronal plane parallel with the bed (see **Fig. 3.84**). Poor side-to-side CR alignment projects the manubrium and clavicles in the direction that the CR is angled, causing the manubrium and sternal ends of the clavicles to be situated more toward the right or left side of the vertebral column and rotation to be demonstrated. One should also evaluate the head position. The chest tends to rotate in the same direction that the face is rotated toward. Rotation is detected by evaluating the distance between the vertebral column and the sternal ends of the clavicles, and by comparing the length of the right and left inferior posterior ribs. Both should be equal on each side. When the right sternal clavicular end is seen superimposing the vertebral column and the right side demonstrates less posterior rib length than the left, the CR was angled toward the left side (**Fig. 3.85**).

When the right sternal clavicular end demonstrates no superimposition of the vertebral column and the right posterior ribs demonstrate greater length than the left, the CR was angled toward the right side (Figs. **3.86** and **3.87**).

CR and Midcoronal Plane Alignment

The neonate/infant lacks the kyphotic curvature in the thoracic vertebrae that the child and adult display. As a result, the supine AP chest tends to have a lordotic appearance when compared with that of a child or adult. The lordotic appearance is demonstrated on AP chest projection when an anterior rib is demonstrated superior to its corresponding posterior rib. When the CR and IR are aligned perpendicular, the AP chest demonstrates

each upper anterior rib superior to its corresponding posterior rib, whereas each lower anterior rib is demonstrated below its corresponding posterior rib (see **Fig. 3.83**). The dividing point for this appearance change is where the CR was centered. Because the chest in neonates/infants is shorter than in children and adults, a common error is to center the CR too inferiorly. This inferior CR centering only results in an increase in the lordotic appearance, because additional ribs demonstrate the anterior rib superior to its corresponding posterior rib (**Fig. 3.88**). Such distortion foreshortens the lungs and mediastinal structures, causing the cardiac apex to appear upwardly tilted and the main pulmonary artery to be concealed beneath the cardiac silhouette.

Alternate CR and IR Alignment

To produce an AP chest without the lordotic appearance, a 5-degree caudal angle can be placed on the CR or the foot end of the bed can be tilted 5 degrees lower than the head end. This CR and IR alignment will place each anterior rib below its corresponding posterior rib and demonstrate the posterior ribs with a gentle, superiorly bowed contour (Figs. **3.86** and **3.89**).

Chin Position

To prevent the chin from being superimposed on the airway and apical lung field, lift the neonate or infant's chin until the neck is in a neutral position. When the chin is superimposed on the airway and apical lung field, ETT placement cannot be evaluated (see **Fig. 3.89**).

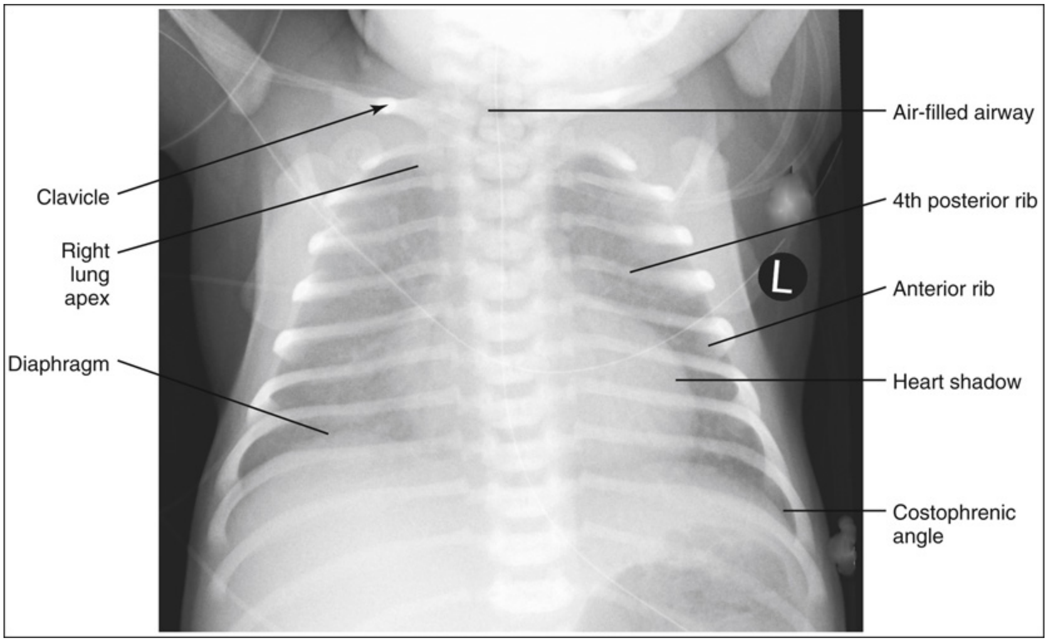


FIGURE 3.83 Neonate AP chest projection with accurate positioning.

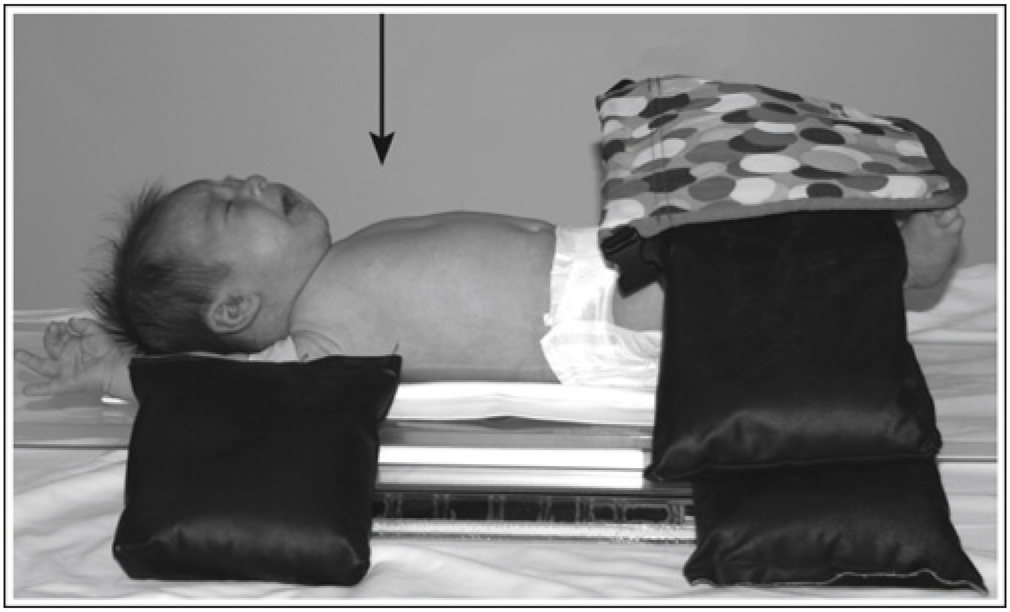


FIGURE 3.84 Proper patient positioning for AP infant chest projection using immobilization equipment.

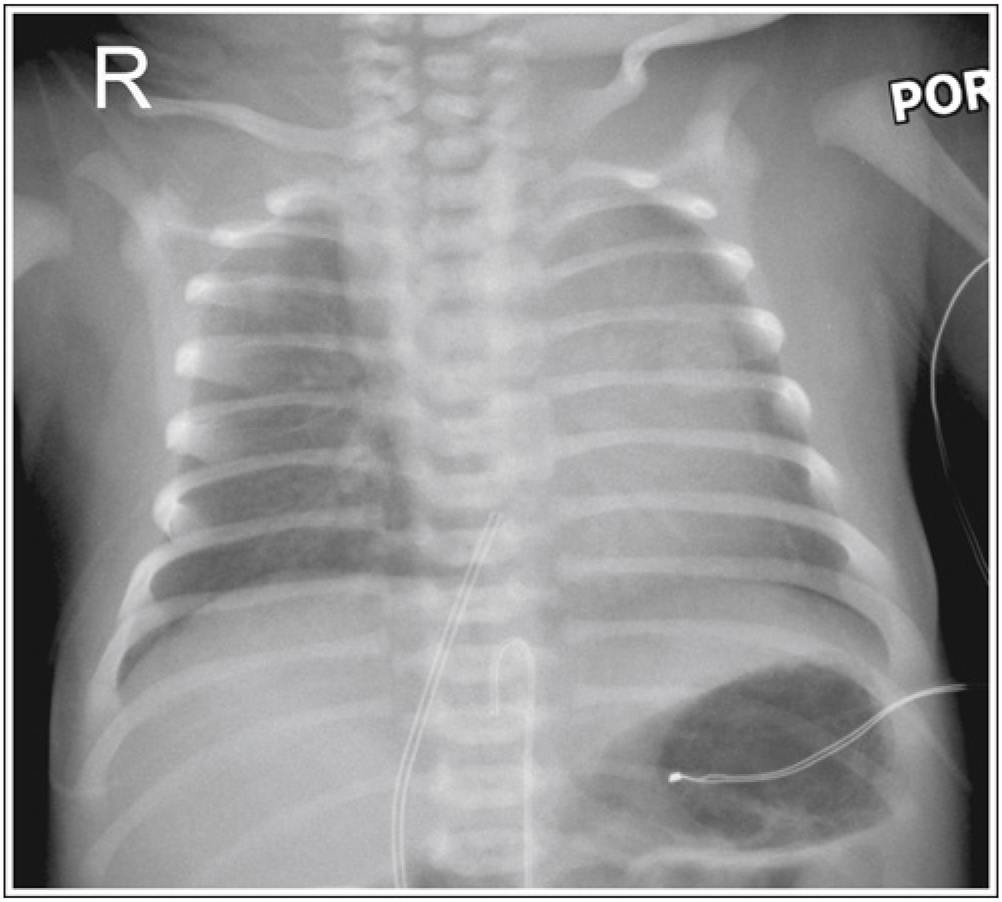


FIGURE 3.85 Neonate AP chest taken with the CR angled toward the left side of the chest.

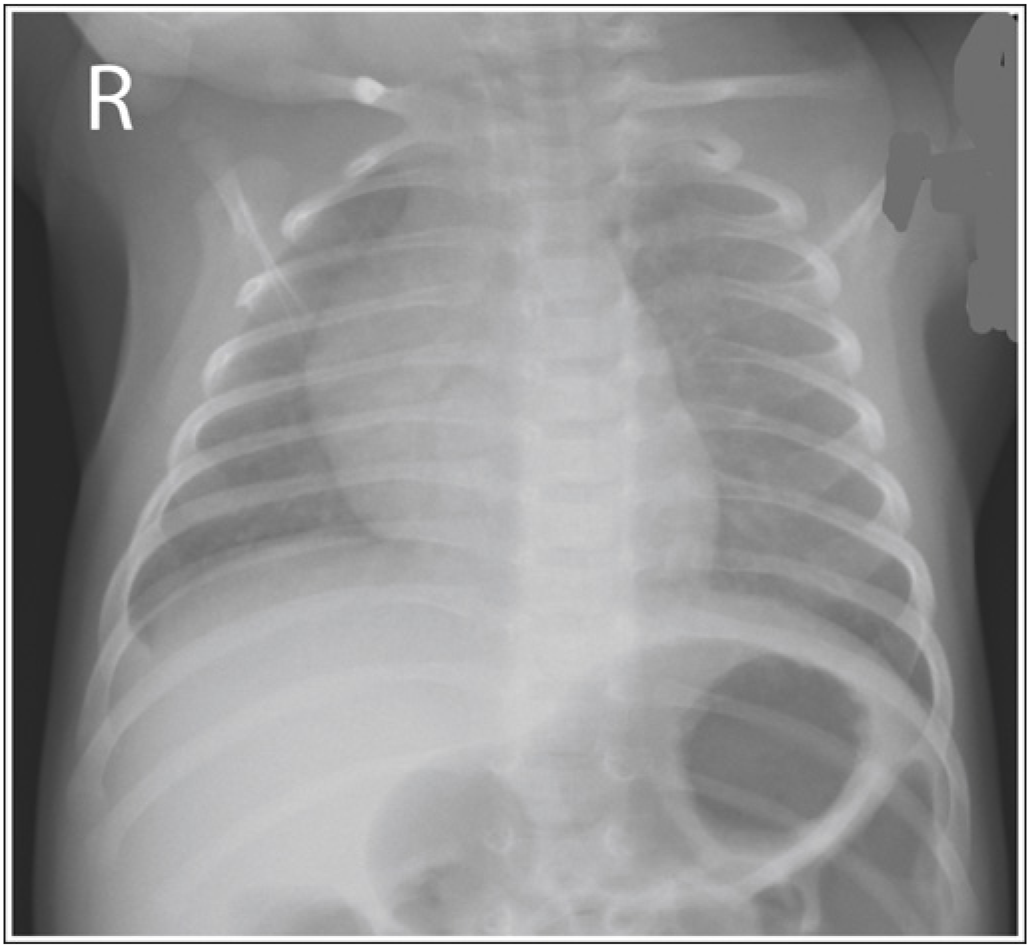


FIGURE 3.86 Neonate AP chest taken with the CR angled toward the right side of the chest and a 5-degree caudal CR angle.

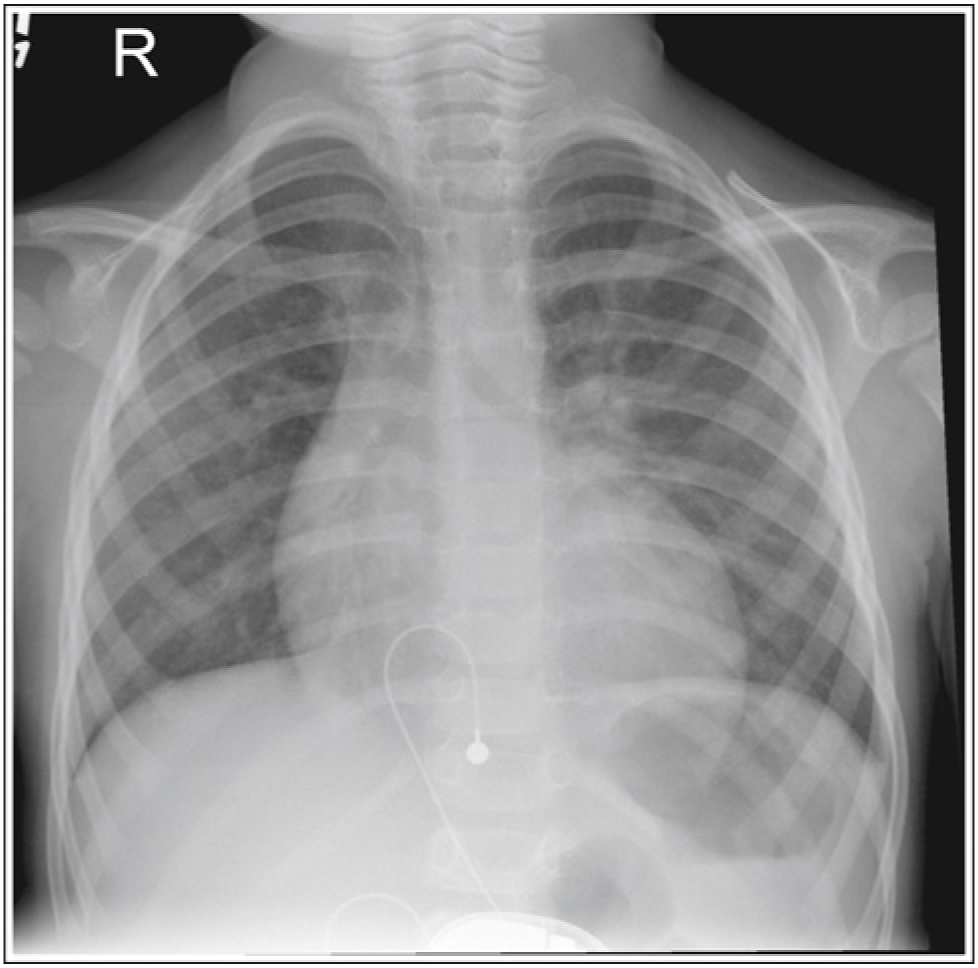


FIGURE 3.87 Infant AP chest taken with the CR angled toward the right side of the chest.

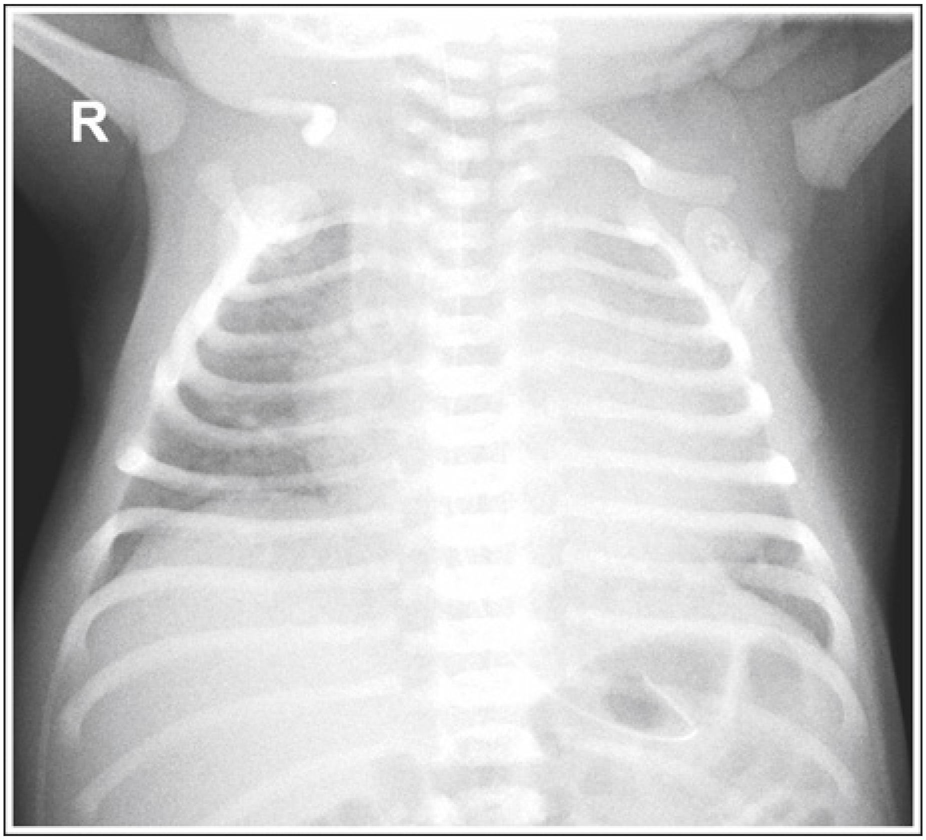


FIGURE 3.88 Neonate AP chest obtained without a caudal CR angle and low CR centering.

TABLE 3.9

CR, Central ray; *IR*, image receptor.

Appearance of Lungs and Aeration

The appearance of the neonate's lungs may change with even one rib's difference in inflation. With dense substances such as blood, pus, protein, and cells filling the alveoli, it is the addition of the less dense air that will

give the projection the fluffy appearance, because the air is demonstrated on the projection with less brightness when compared with the blood, pus, protein, and cells. A lung that demonstrates a white-out appearance, even though the diaphragm is below the eighth rib, is filled with dense substances that do not allow air to fill the alveoli. The high-frequency ventilator is most commonly used on neonates/infants. This ventilator allows the exposure to be made at any time because it maintains the lung expansion at a steady mean pressure. For neonates and infants breathing without a respirator, observe the chest movement and expose the projection after the infant takes a deep breath.

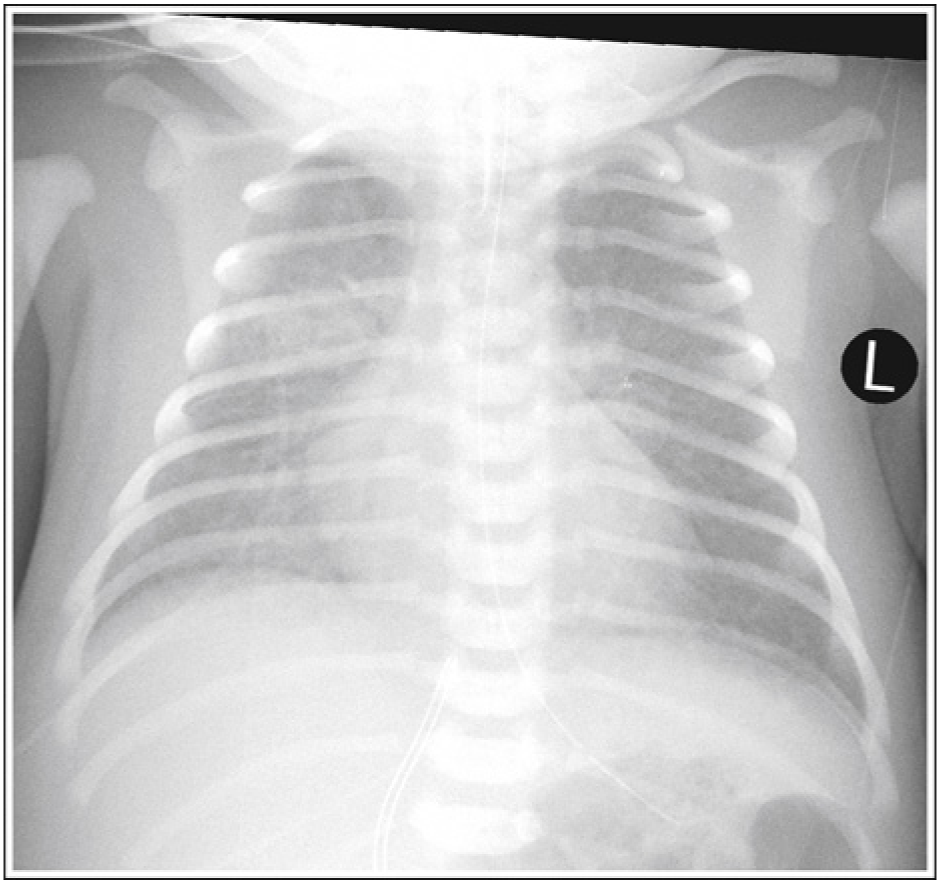


FIGURE 3.89 Neonate AP chest obtained with a 5-degree caudal CR angle and chin not elevated.

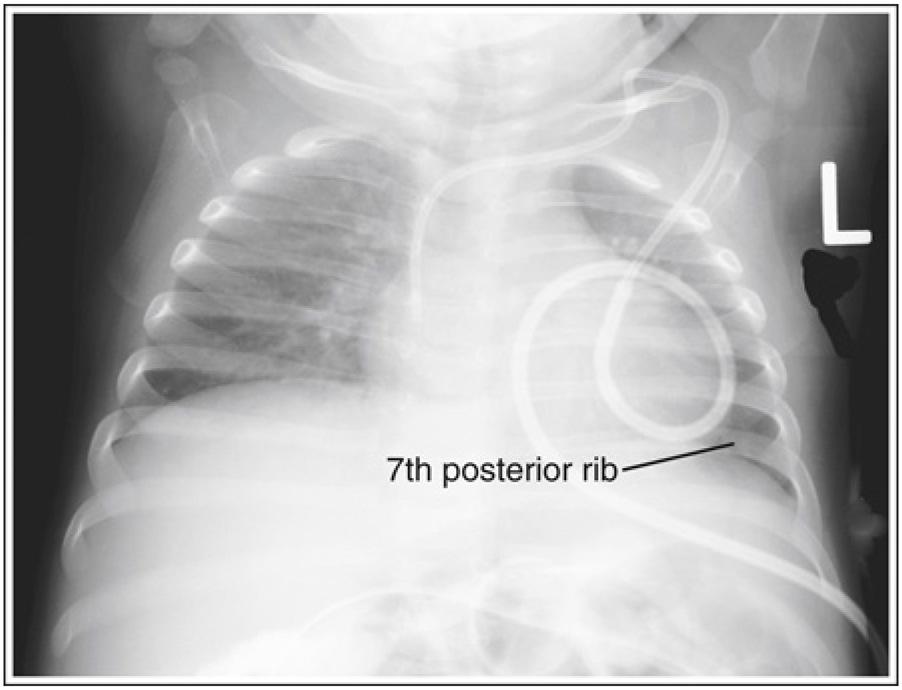


FIGURE 3.90 Neonate AP chest without full lung aeration.

Lung Aeration

If fewer than eight posterior ribs are demonstrated above the diaphragm for the neonate and nine for the infant, the lungs were not fully inflated. Chest projections that are taken with inadequate inspiration demonstrate a wider-appearing heart shadow and an increase in lung tissue brightness, because the decrease in air volume increases the concentration of pulmonary tissues (Figs. **3.90** and **3.91**). Before repeating the procedure, evaluate the order history and previous projections, if available, to determine whether a patient's condition might have caused the poor inhalation.

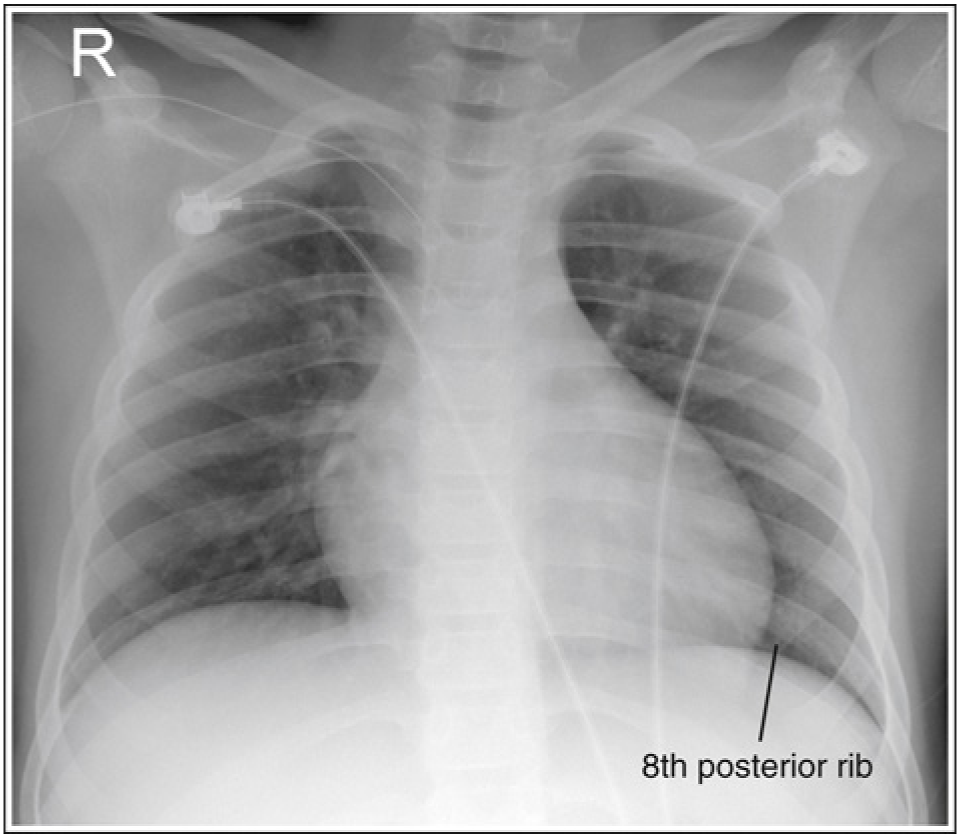


FIGURE 3.91 Infant AP chest without full lung aeration.

Neonate and Infant AP Chest Analysis Practice

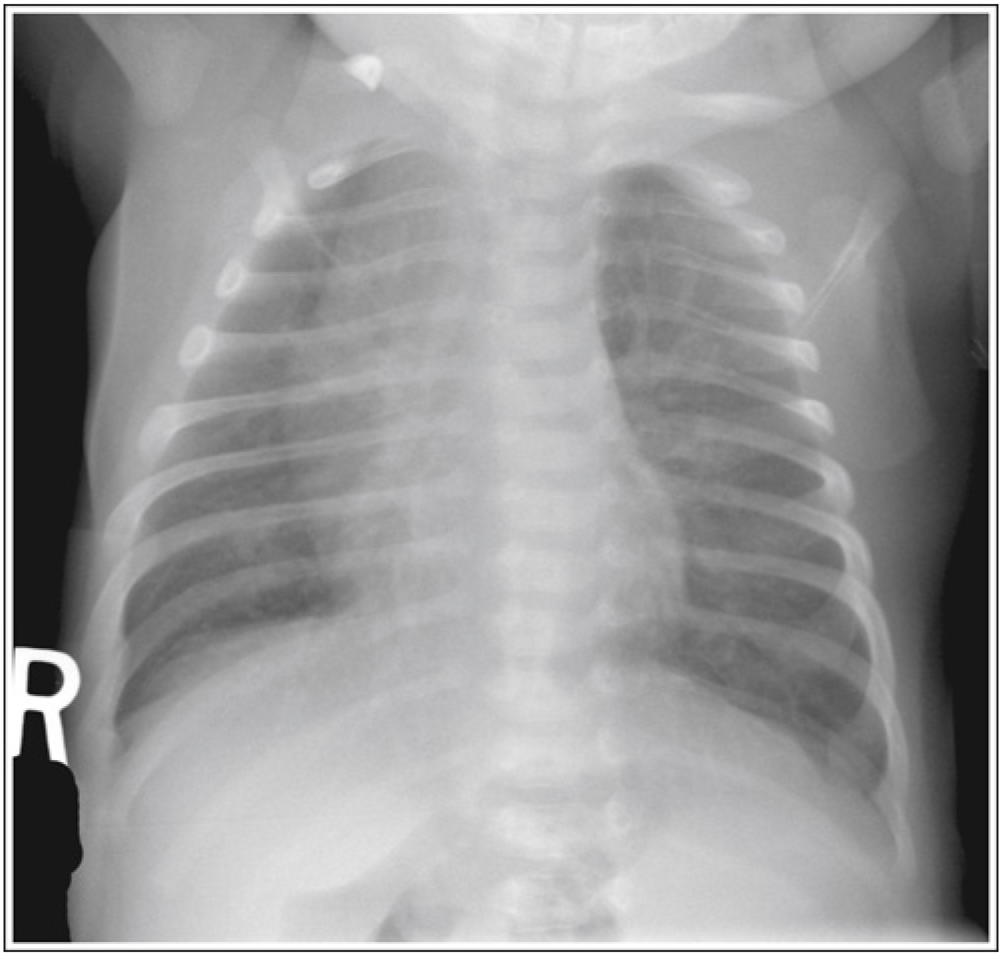


IMAGE 3.16

NEONATE.

Analysis

The right sternal clavicular end is demonstrated further from the vertebral column than the left, and the right posterior ribs are longer than the left. The right side of the chest is rotated toward the IR, or the CR was angled toward the right lateral side.

Correction

Rotate the right side of the chest away from the IR until the midcoronal plane is parallel with the IR and perpendicular to the CR.

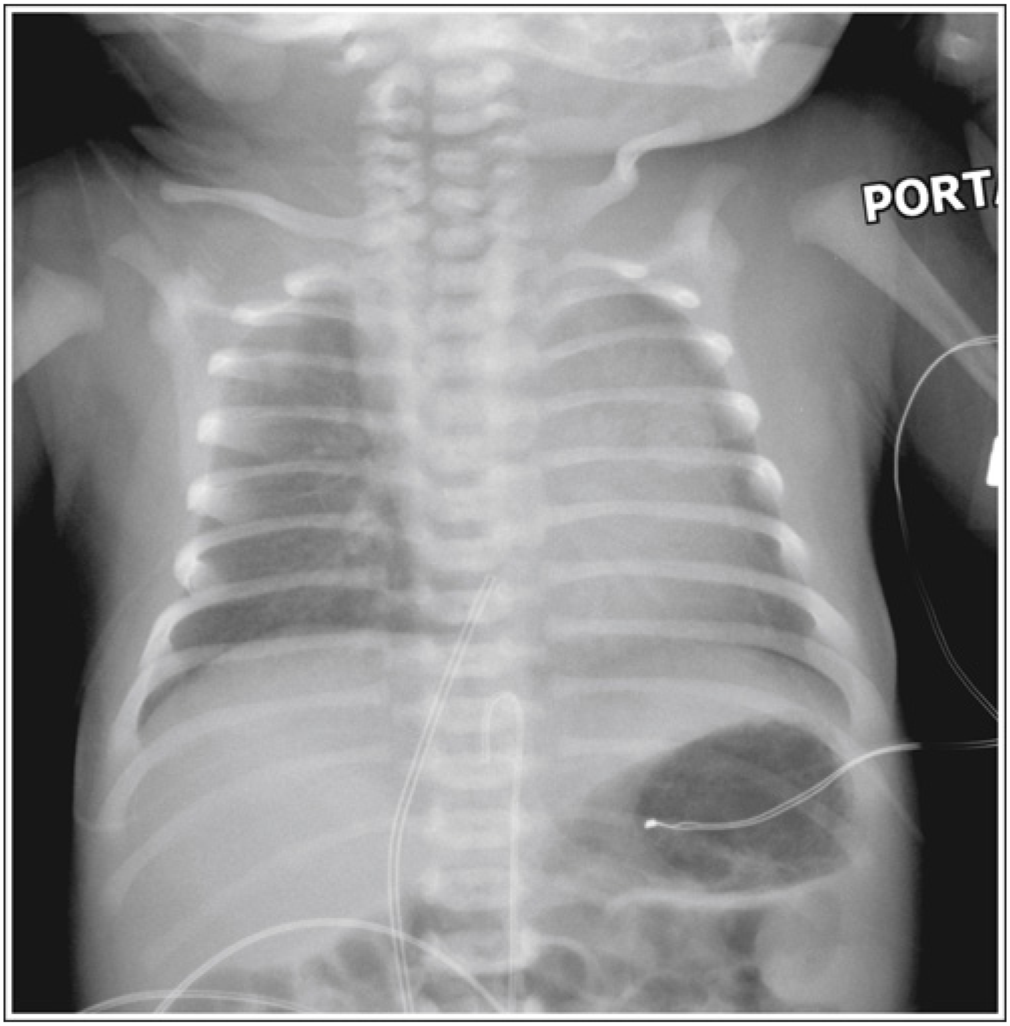


IMAGE 3.17

NEONATE.

Analysis

The left sternal clavicular end is demonstrated further from the vertebral column than the right, and the left-side posterior ribs are longer than the right. The head is turned so the face is toward the left side. The left side of the chest is rotated toward the IR.

Correction

Rotate the left side of the chest away from the IR until the midcoronal plane is parallel with the IR and perpendicular to the CR. Turn the head so the face is forward.

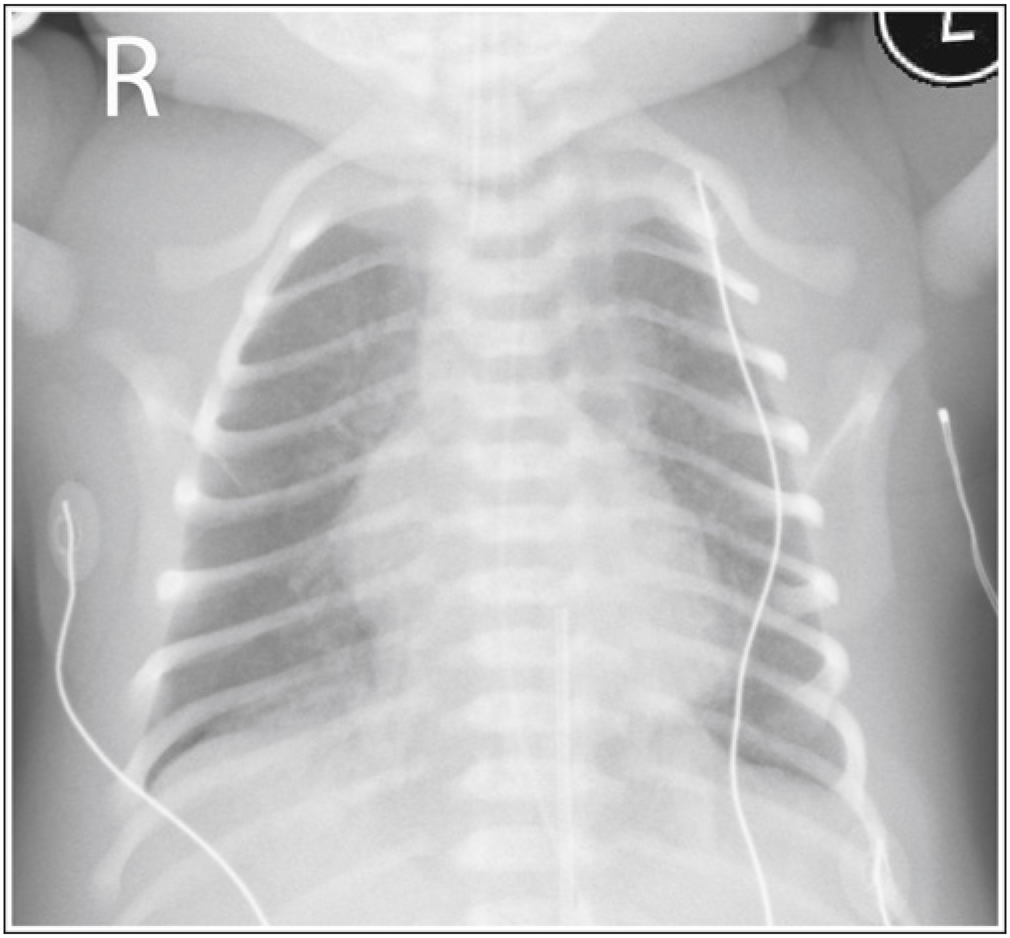


IMAGE 3.18

NEONATE.

Analysis

Each of the upper anterior ribs is demonstrated superior to its corresponding posterior rib. The chest is lordotic. The CR was angled too cephalically.

Correction

Decrease the cephalic angulation until the CR and IR are perpendicular, or lower the foot end of the bed until the midcoronal plane and CR are within

5 degrees of perpendicular.

Child Chest: PA and AP (Portable) Projections

See **Table 3.10** and Figs. **3.92** and **3.93**.

TABLE 3.10

CR, Central ray; *IR*, image receptor.

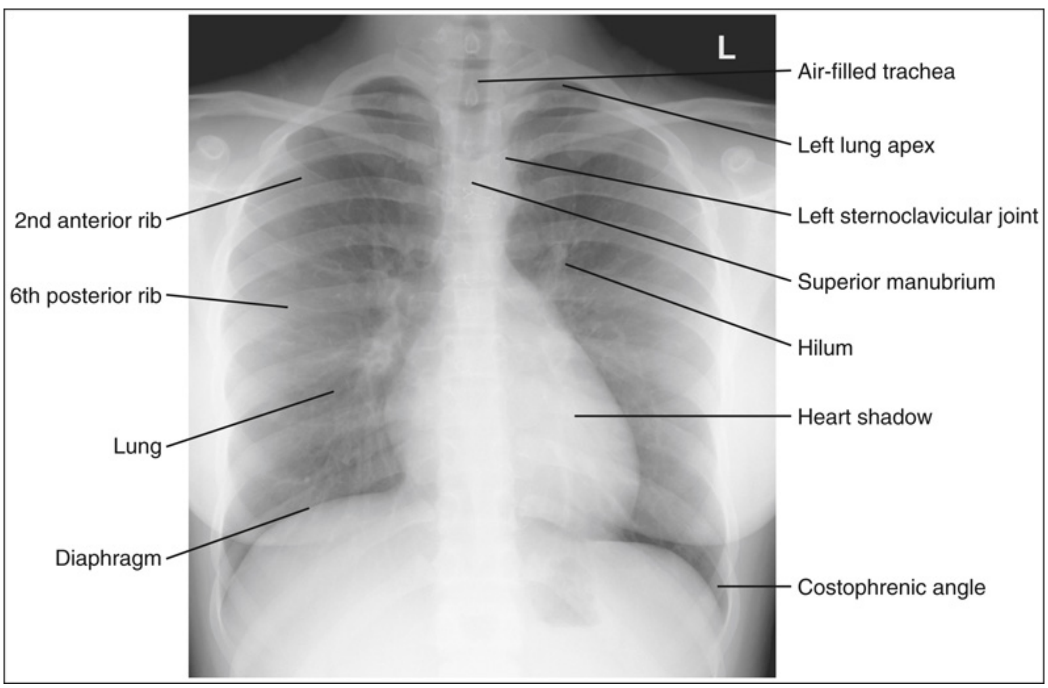


FIGURE 3.92 Child AP chest projection with proper positioning.

FIGURE 3.93 Proper patient positioning for a child AP chest projection.

The image analysis guidelines of the child PA and AP chest are similar to those for the infant or adult PA or AP chest, as already discussed. The size of the child determines which of the guidelines best meets the situation. For a discussion on topics needed to analyze the following images, refer to the PA-AP (portable) adult or infant chest discussions earlier in this chapter.

Child Chest PA and AP (Portable) Chest Analysis Practice

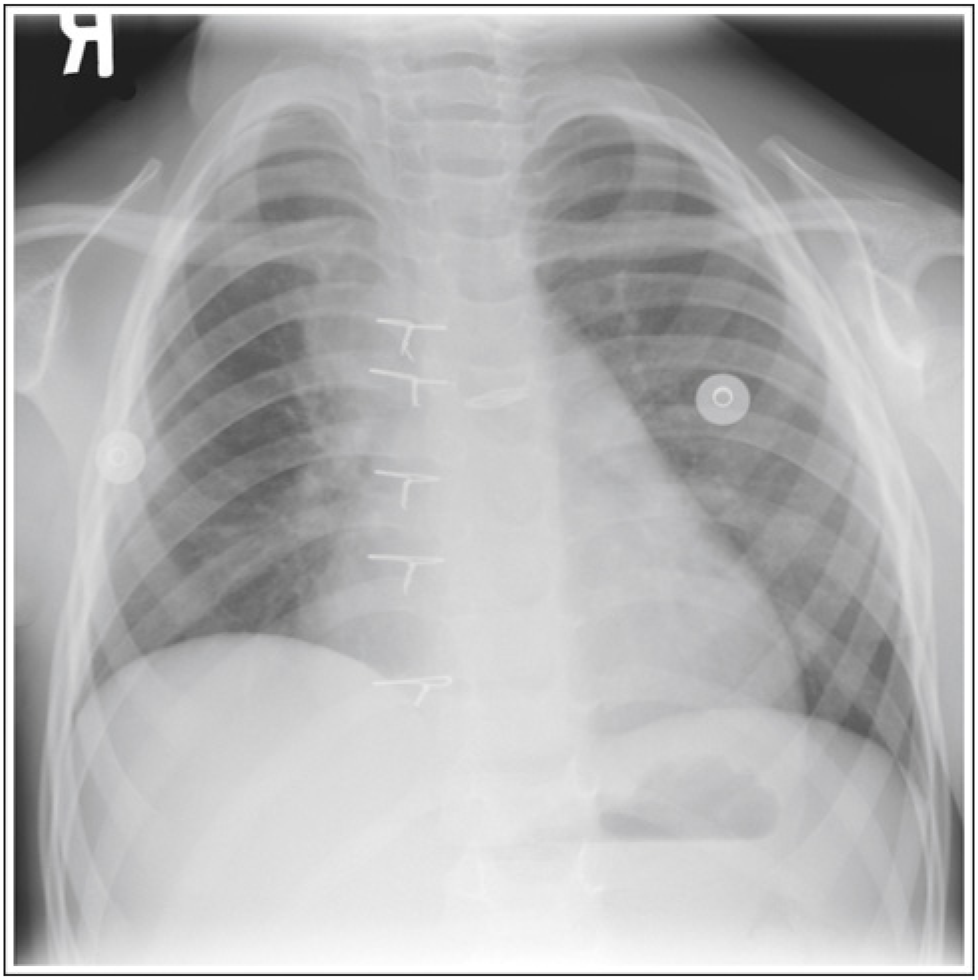


IMAGE 3.19

CHILD—UPRIGHT PA PROJECTION.

Analysis

The right sternal clavicular end is situated farther from the vertebral column than the left. The right side of the chest was rotated away from the IR. The manubrium is situated at the level of the fifth thoracic vertebra. The upper midcoronal plane was tilted anteriorly.

Correction

Rotate the right side of the thorax toward the IR and move the upper thorax away from the IR until the midcoronal plane is parallel with the IR.

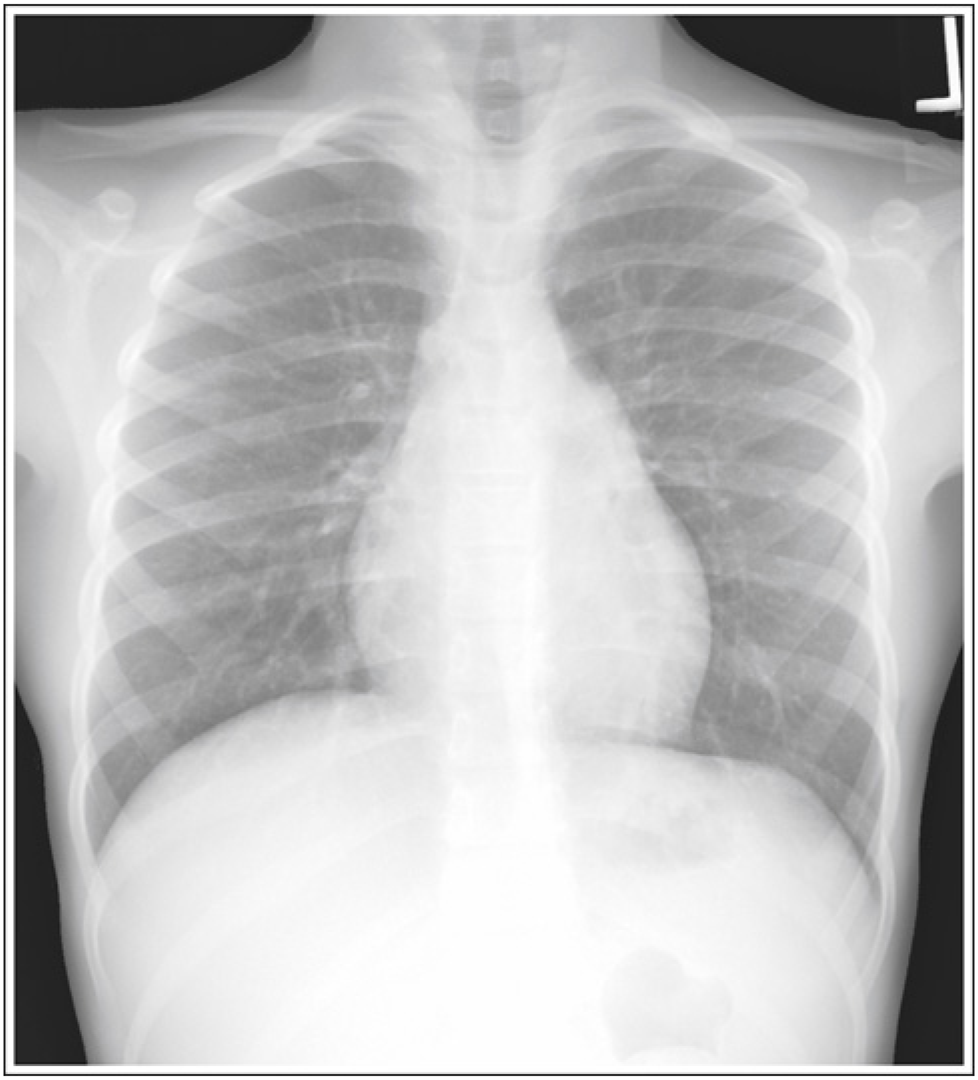


IMAGE 3.20

CHILD—UPRIGHT PA PROJECTION.

Analysis

The manubrium is at the level of the second thoracic vertebra. The upper midcoronal plane was tilted posteriorly.

Correction

Anteriorly tilt the upper midcoronal plane until it is aligned parallel with the IR.

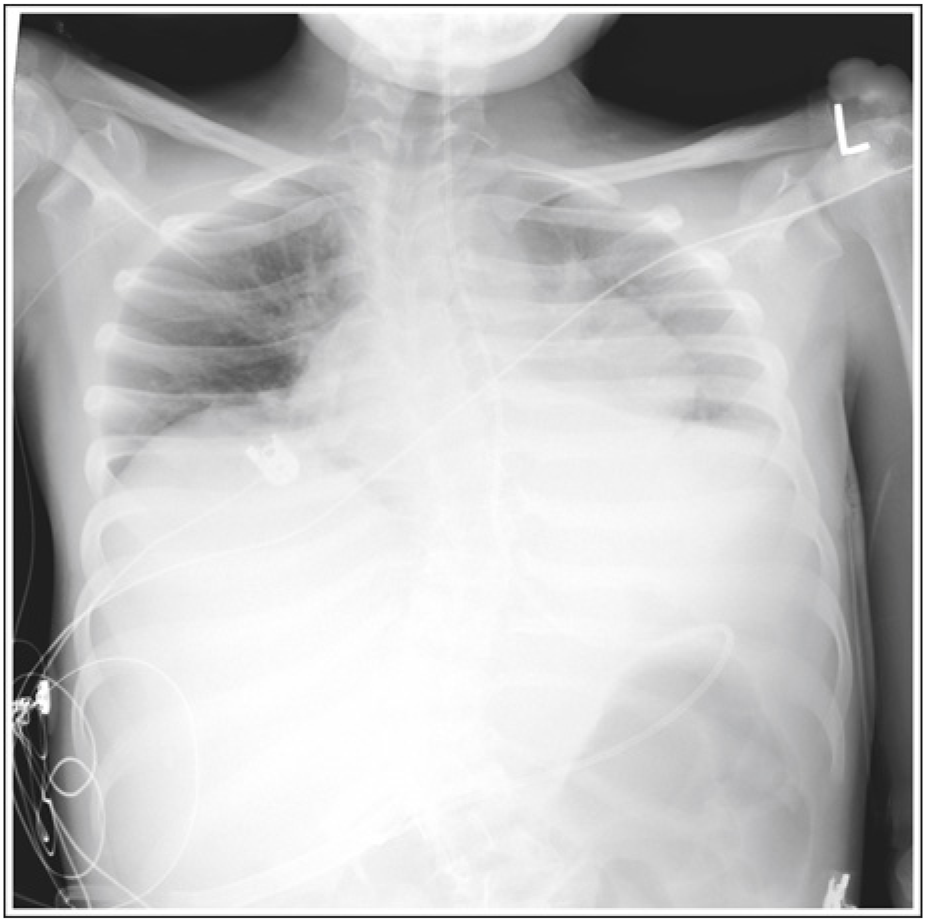


IMAGE 3.21

CHILD—AP (MOBILE) PROJECTION.

Analysis

Only six posterior ribs are demonstrated above the diaphragm. The manubrium is superimposed over the second thoracic vertebra, and the posterior ribs demonstrate a horizontal contour. The projection was taken on expiration, and the CR was angled too cephalically. The right medial clavicle superimposes the vertebral column. The patient is in a slight LPO position.

Correction

If the patient's condition allows, take the exposure after coaxing the patient into a deeper inspiration and adjust the CR caudally until it is aligned perpendicular to the midcoronal plane. Rotate the patient toward the right side until the midcoronal plane is parallel with the IR.

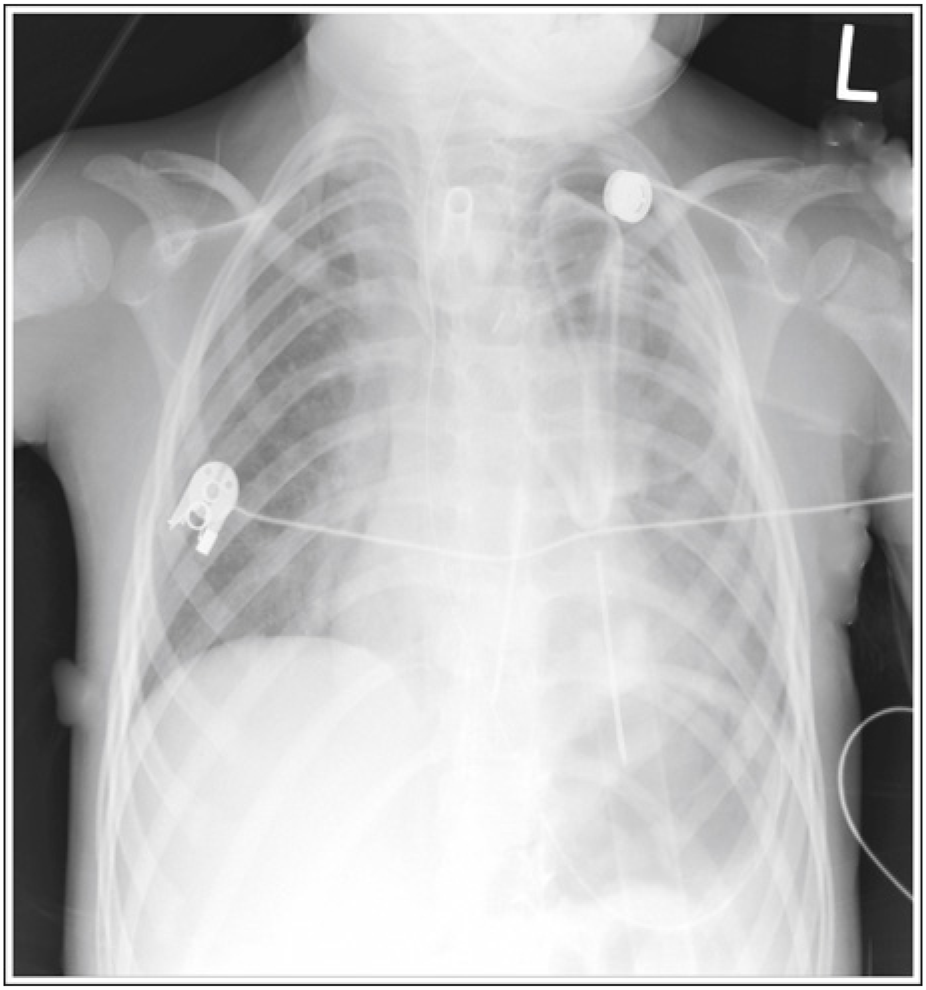


IMAGE 3.22

CHILD—AP (MOBILE) PROJECTION.

Analysis

The manubrium is superimposed over the fifth thoracic vertebra, and the posterior ribs demonstrate a vertical contour. The CR was angled too caudally.

Correction

Adjust the CR cephalically until it is aligned perpendicular to the midcoronal plane.

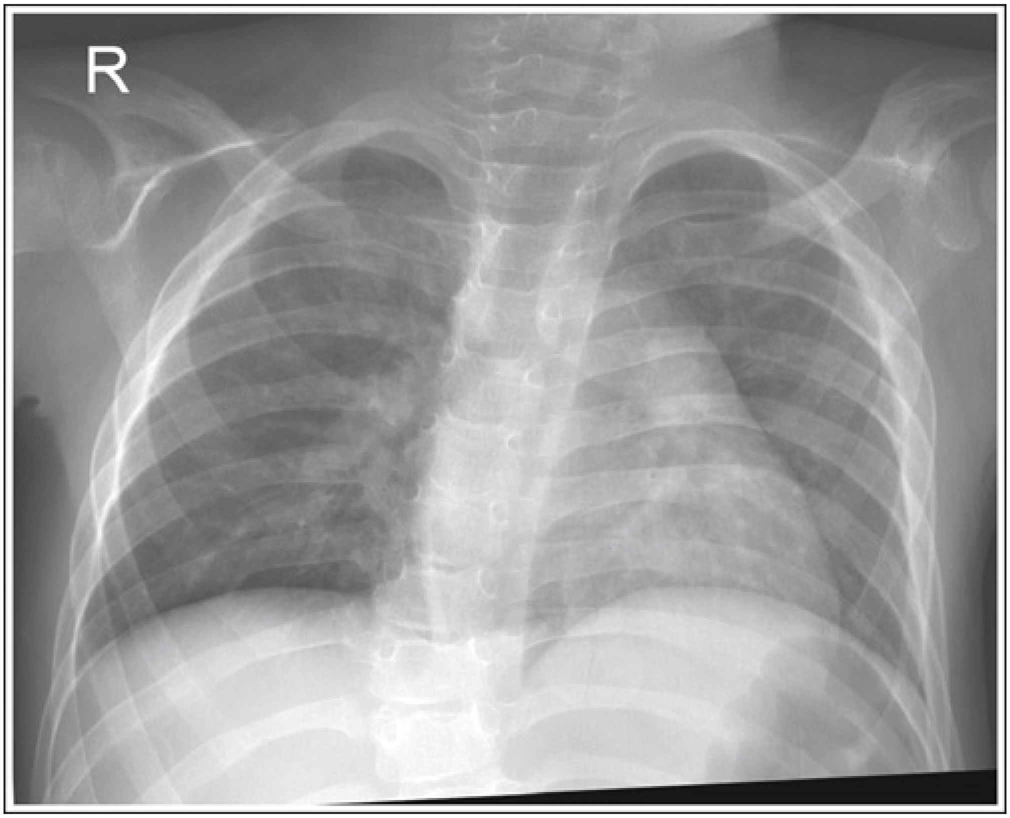


IMAGE 3.23

CHILD—AP (MOBILE) PROJECTION.

Analysis

The left sternal clavicular end is situated farther from the vertebral column than the right. The left side of the patient and IR were placed closer to the bed and farther from the collimator's face than the right side. Only eight posterior ribs are demonstrated above the diaphragm.

Correction

Elevate the left side of the patient and IR or adjust the CR angulation toward the right side of the chest until the collimator's face is parallel with the IR and CR is perpendicular. Coax the patient into a deeper inspiration.

Neonate and Infant Chest: Cross-Table Lateral Projection (Left Lateral Position)

See **Table 3.11** and Figs. **3.94** and **3.95**.

TABLE 3.11

CR, Central ray; *IR*, image receptor.

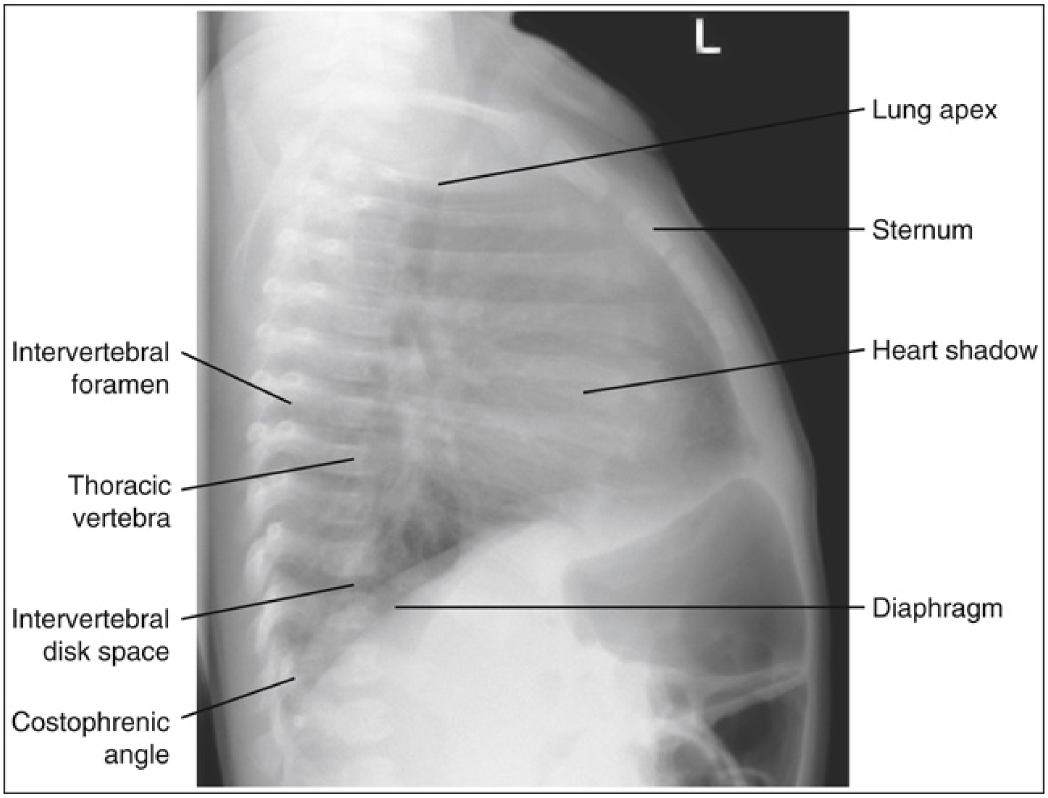


FIGURE 3.94 Neonatal cross-table lateral chest projection with accurate positioning.

FIGURE 3.95 Proper patient positioning for a cross-table lateral infant chest projection using immobilization equipment.

Exam Indication

The lateral chest projection is useful for assessing the degree of inflation, permits confident recognition of cardiomegaly, and provides the clearest view of the thoracic vertebrae and sternum.

Cross-Table Versus Overhead Lateral

Neonates are very sensitive. Performing a cross-table lateral projection on the neonate instead of an overhead lateral projection will reduce the amount of disturbance. Also, on overhead lateral projections, the lung adjacent to the IR tends to collapse from the body weight, whereas the superior lung tends to overinflate.

Chest Rotation: Degree of Posterior Rib Superimposition

Because the OID difference between the right and left lung fields is minimal on neonates and small infants, the posterior ribs on lateral chest do not demonstrate the 0.5-inch (1.25-cm) separation that is seen on the adult lateral chest when they are accurately positioned. Instead, the ribs are directly superimposed. To detect rotation on neonate and infant lateral chest projections, evaluate the degree of superimposition of the posterior ribs. When the posterior ribs are demonstrated without superimposition, the chest was rotated for the projection (Figs. **3.96** and **3.97**).

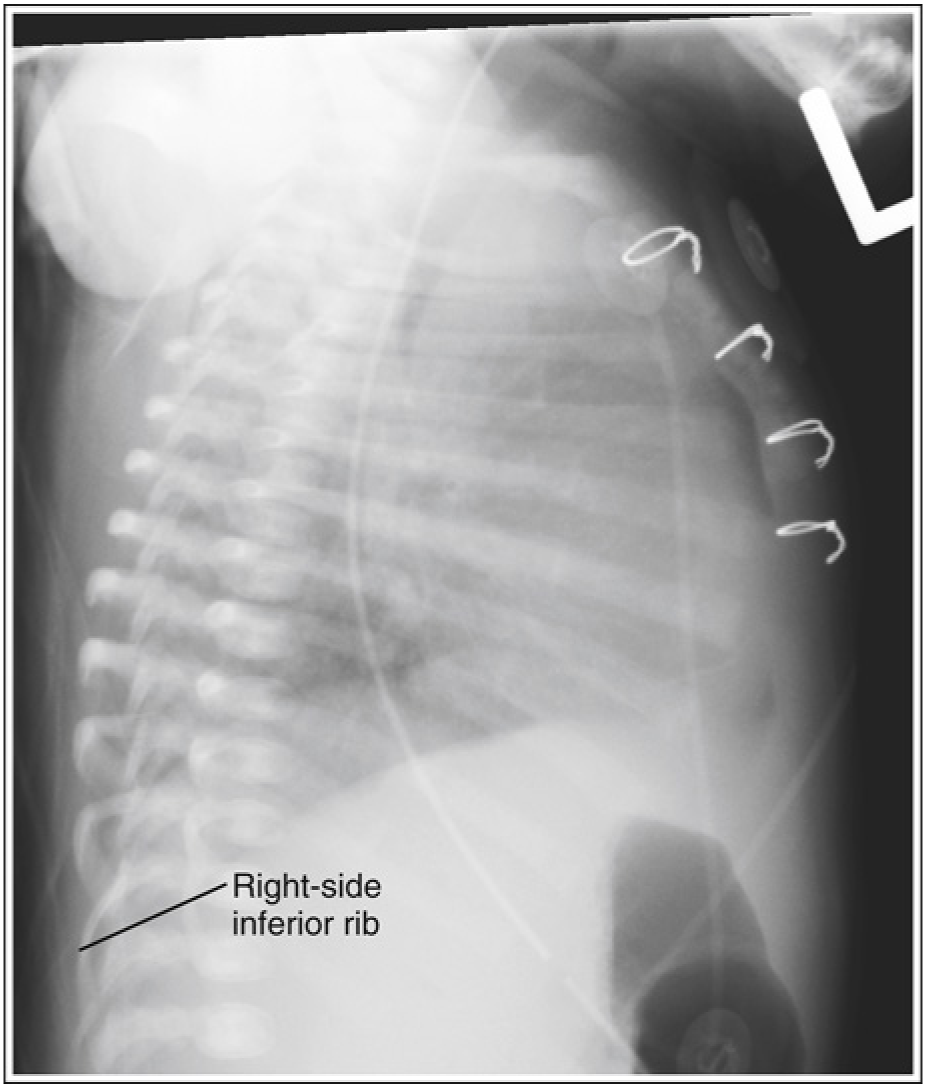


FIGURE 3.96 Neonate lateral chest taken with right lung rotated posteriorly.

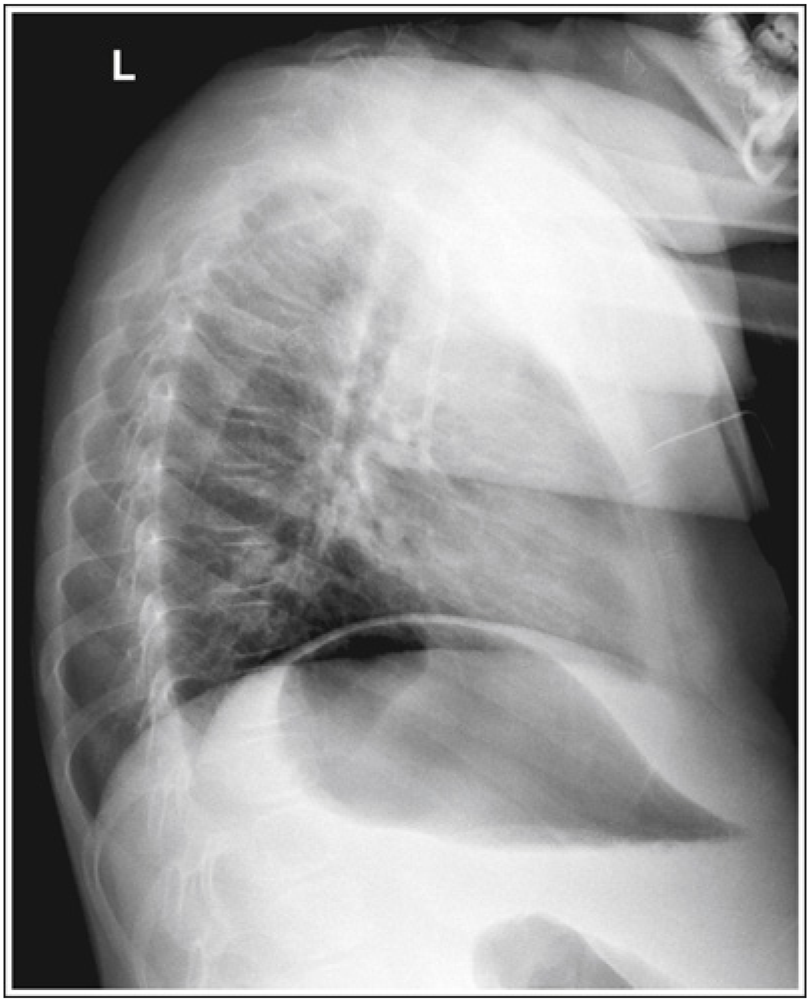


FIGURE 3.97 Infant lateral chest taken with right lung rotated posteriorly and humeri not elevated.

One means of identifying the lung that is positioned posteriorly on a rotated lateral chest projection is to locate the most inferiorly demonstrated right and left corresponding ribs. The rib on the right side will be projected slightly more inferiorly than the rib on the left side, because it is positioned farthest from the IR. The heart shadow and gastric bubble may also be used, as described in the earlier discussion of the adult lateral chest projections.

Arms

Positioning the humeri upward, near the head, prevents superimposition of the humeral soft tissue over the anterior lung apices (see **Fig. 3.97**).

Chin

Good radiation protection practices dictate that anatomic structures that are not evaluated on a projection should not be included, whenever possible. To prevent the chin from being included in the exposure field, lift it upward above the collimation field (**Fig. 3.98**).

Respiration

For neonates and infants breathing without a respirator, observe the chest movement and take the exposure after the infant takes a deep breath. Chest projections that are taken on expiration may demonstrate an increase in image brightness because the decrease in air volume increases the concentration of pulmonary tissues. With under-aeration, the cephalic curve of the hemidiaphragms is exaggerated and their position is higher in the thorax (**Fig. 3.99**).

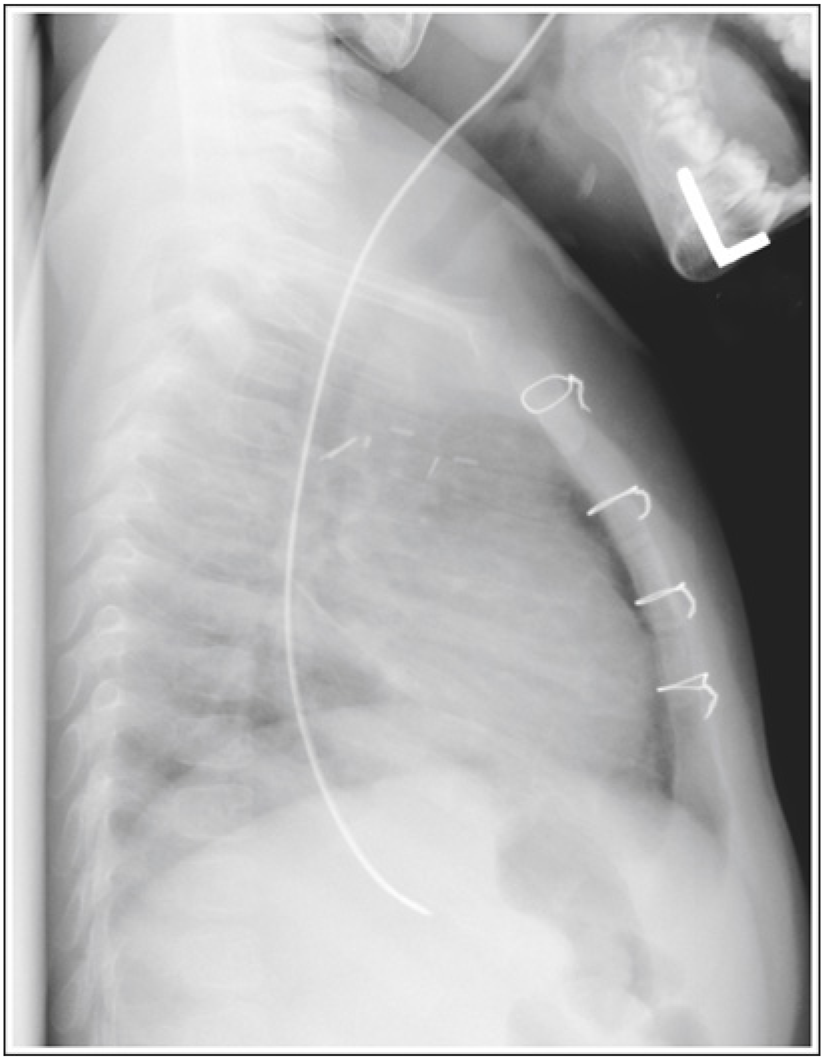


FIGURE 3.98 Infant lateral chest taken with chin in exposure field.

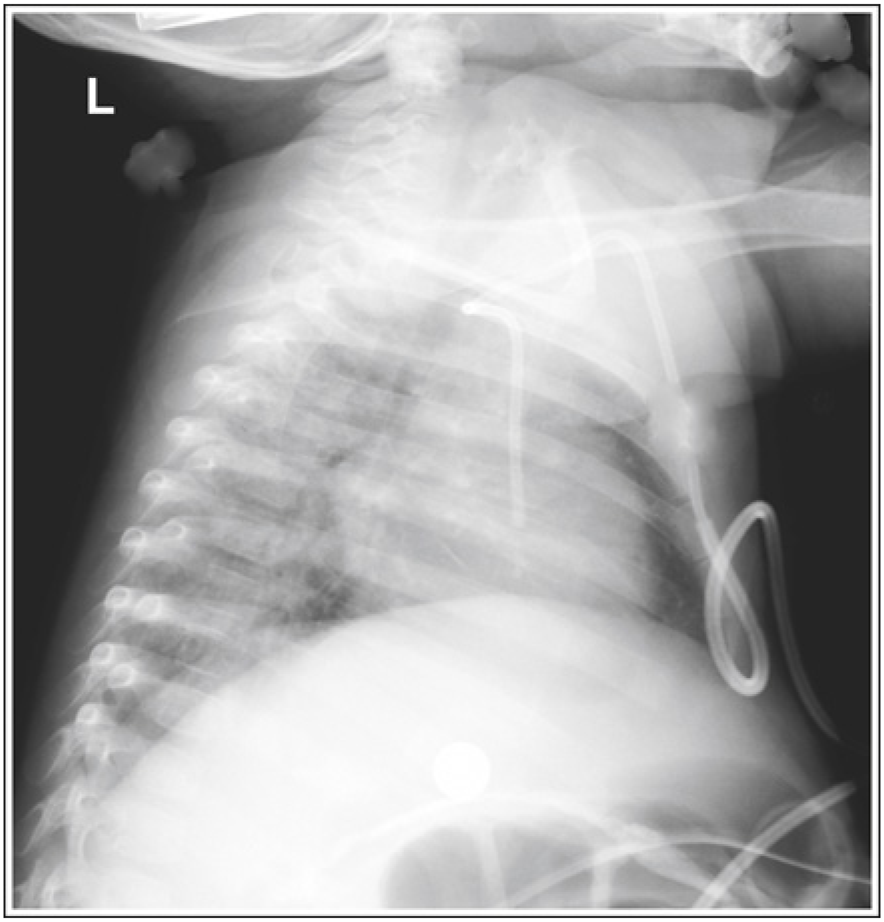


FIGURE 3.99 Neonate lateral chest without full lung aeration.

Child Chest: Lateral Projection (Left Lateral Position)

See **Table 3.12** and Figs. **3.100** and **3.101**.

The analysis of the child lateral chest projection (see **Table 3.12**) is the same as that of the infant or adult lateral chest projection (see earlier). The size of the child determines which image analysis guidelines best meet the situation. For a discussion on the topics needed to analyze the following images, see the lateral adult or infant chest discussions earlier in this chapter.

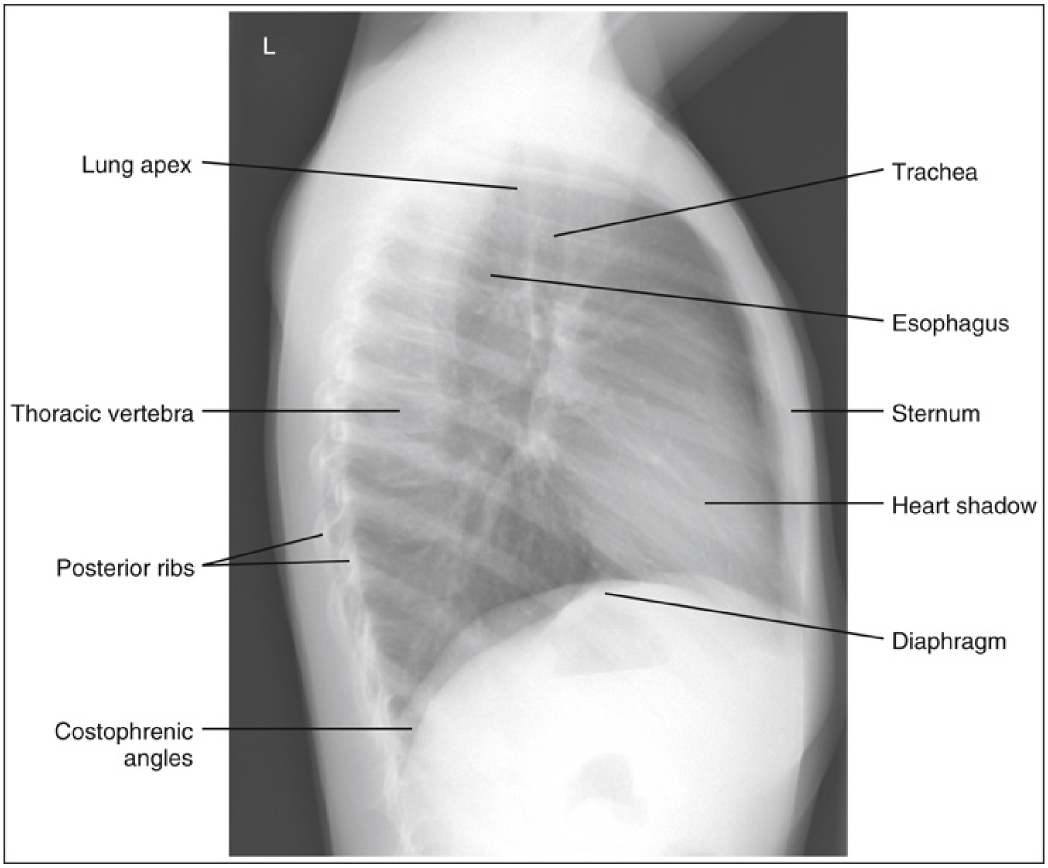


FIGURE 3.100 Child lateral chest projection with accurate positioning.

FIGURE 3.101 Proper positioning for a child lateral chest projection.

TABLE 3.12

CR, Central ray; *IR*, image receptor.

Child Lateral Chest Analysis Practice

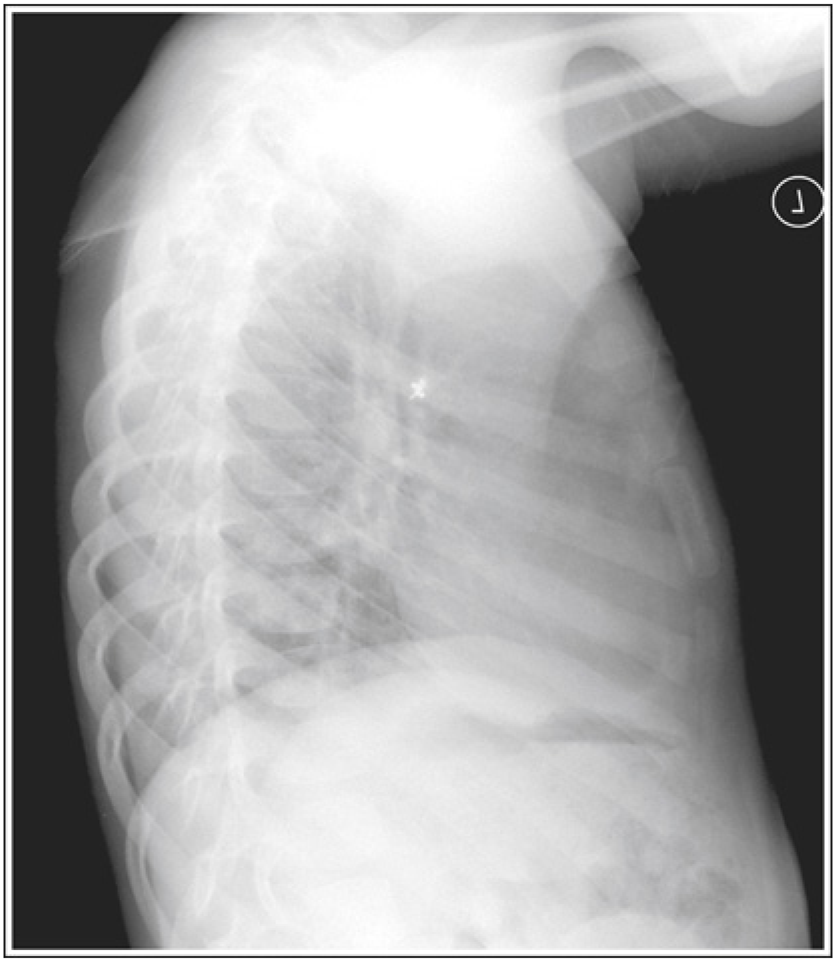


IMAGE 3.24

CHILD.

Analysis

More than 0.5 inch (1.25 cm) of separation is demonstrated between the posterior ribs. The right lung is posterior. The mandible is within the exposure field, and the humeral soft tissue is superimposed over the superior lung field. The chin and the humeri were not adequately elevated.

Correction

Rotate the right side of the thorax anteriorly and the left side posteriorly until the midcoronal plane is aligned perpendicular to the IR. Elevate the chin outside the collimated field, and raise the humeri next to the head.

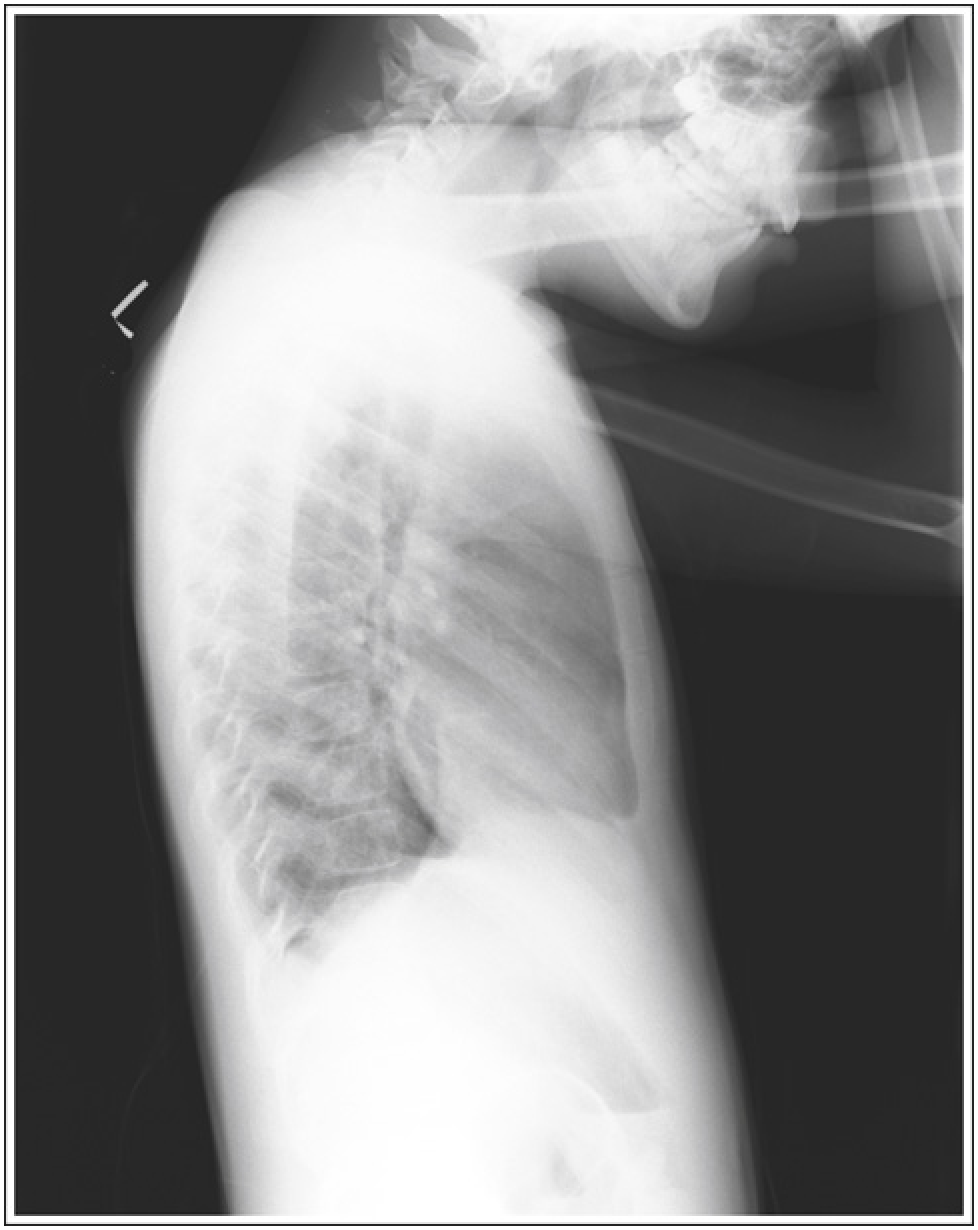


IMAGE 3.25

CHILD.

Analysis

The arms and mandible are demonstrated in the exposure field. Poor collimation is demonstrated.

Correction

Increase the longitudinal collimation to the shoulder top and inferior ribs and transverse collimation to within 0.5 inch (1.25 cm) of thorax skin line. Raise the chin and humeri out the collimated field.

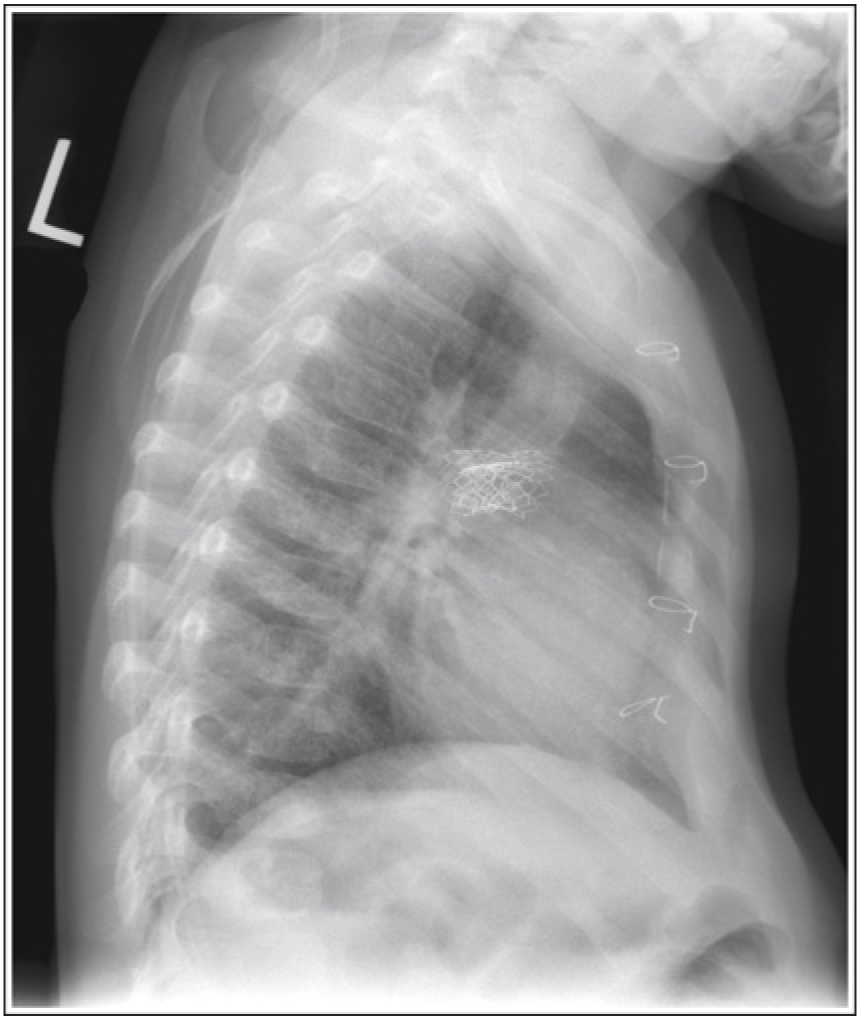


IMAGE 3.26

CHILD.

Analysis

More than 0.5 inch (1.25 cm) of separation is demonstrated between the posterior ribs. The left lung is anterior. The mandible is within the exposure field. The chin was not adequately elevated.

Correction

Rotate the right side of the thorax anteriorly and the left side posteriorly until the midcoronal plane is aligned perpendicular to the IR. Elevate the chin outside the collimated field.

Neonate and Infant Chest: AP Projection (Right or Left Lateral Decubitus Position)

See **Table 3.13** and Figs. **3.102** and **3.103**.

Preventing Artifact Lines in Lung Field

Elevating the neonate or infant on a radiolucent sponge prevents the chest from sinking into the pad. When the body is allowed to sink into the pad, artifact lines are seen superimposed over the lateral lung field of the side adjacent to the cart (**Fig. 3.104**). Because fluid in the pleural cavity gravitates to the lowest level, it is in this area that the fluid will be demonstrated, and superimposition of the pad and lower lung field may obscure fluid that has settled in the lowest level.

Midsagittal Plane Tilting

If the neonate or infant's entire body is placed on the radiolucent sponge, the midsagittal plane can be aligned parallel with the bed or cart, preventing lateral tilting (Figs. **3.104** and **3.105**).

Chest Rotation

Chest rotation is detected on an AP (lateral decubitus) projection by evaluating the distance between the vertebral column and the sternal ends of the clavicles, and by comparing the length of the right and left inferior posterior ribs. The sternal clavicular end that is superimposed over the least amount of the vertebral column, along with the side of the chest that

demonstrates the longest posterior ribs, represents the side of the chest toward which the infant is rotated (Figs. **3.105** and **3.106**).

TABLE 3.13

CR, Central ray; *IR*, image receptor.

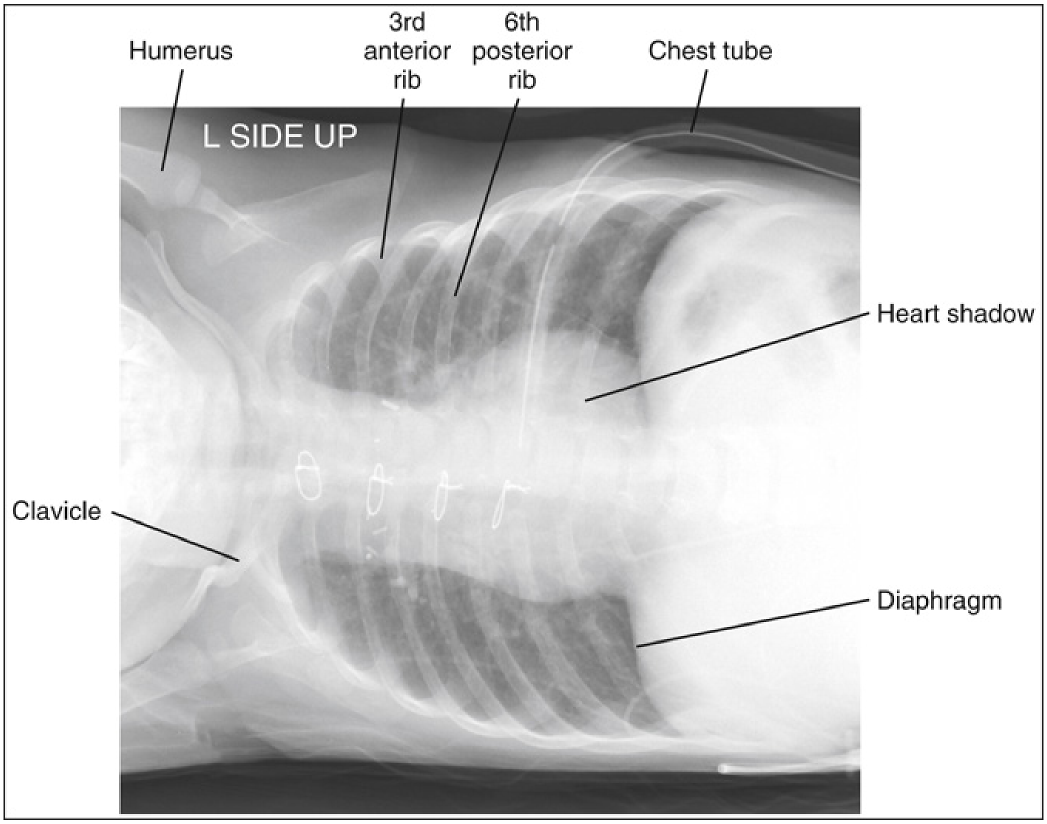


FIGURE 3.102 Neonate AP (right lateral decubitus) chest projection with accurate positioning.

FIGURE 3.103 Proper patient positioning for AP (left lateral decubitus) neonate and infant chest projection.

Chin and Arm Positioning

To prevent the chin from being superimposed over the lung apices on the projection, elevate the chin until the neck is in a neutral position (see **Fig. 3.106**). Placing the arms upward toward the head positions them away from the lung field and projects the lateral clavicles in an upward position (Figs. **3.106** and **3.107**).

CR and IR Alignment

As discussed in the AP neonate/infant chest projection previously, because of the lack of thoracic kyphotic curvature, the resulting image can take on an excessive lordotic appearance without appropriately centering the CR or adjusting the CR and IR alignment. When the neonate/infant's upper

posterior surface rests against the IR and a perpendicular CR is used, the AP decubitus chest will demonstrate each upper anterior rib superior to its corresponding posterior rib, whereas each lower anterior rib is demonstrated below its corresponding posterior rib (Figs. **3.106** and **3.108**). The dividing point for this appearance change is where the CR was centered.

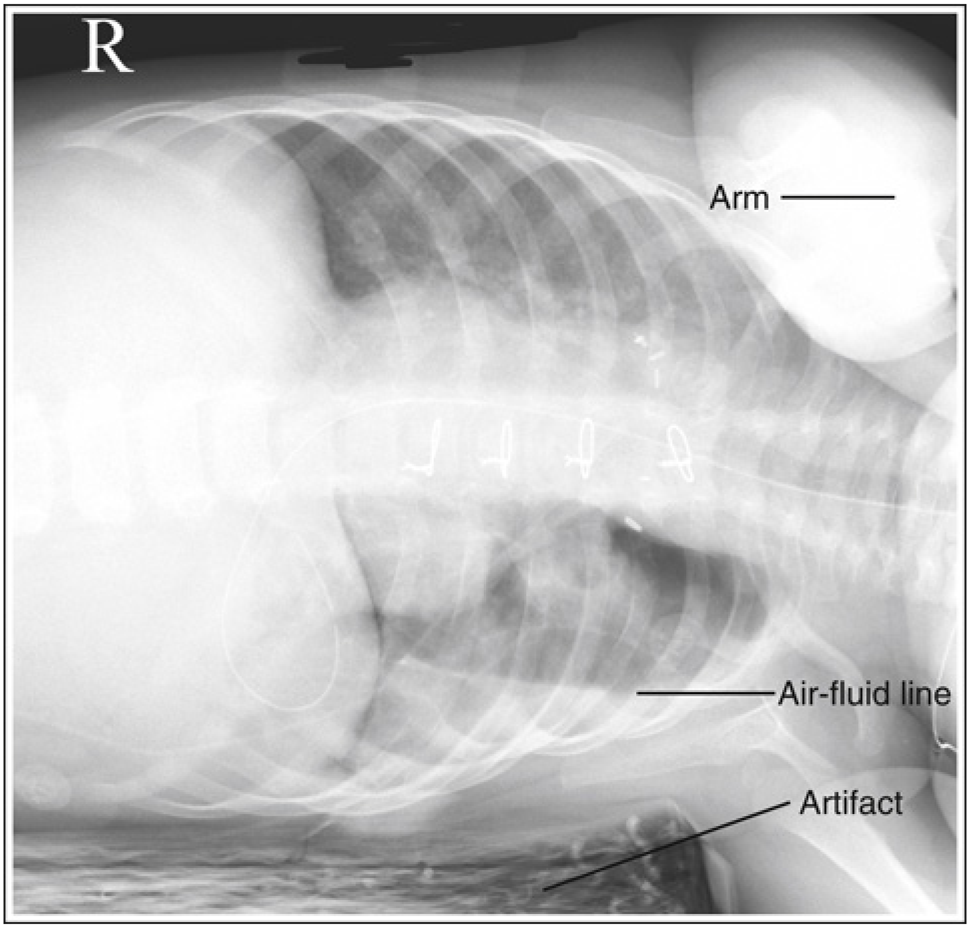


FIGURE 3.104 Neonate AP (left lateral decubitus) chest demonstrating left side pleural effusion, a pad artifact, lateral tilting of the midsagittal plane, and right arm not elevated.

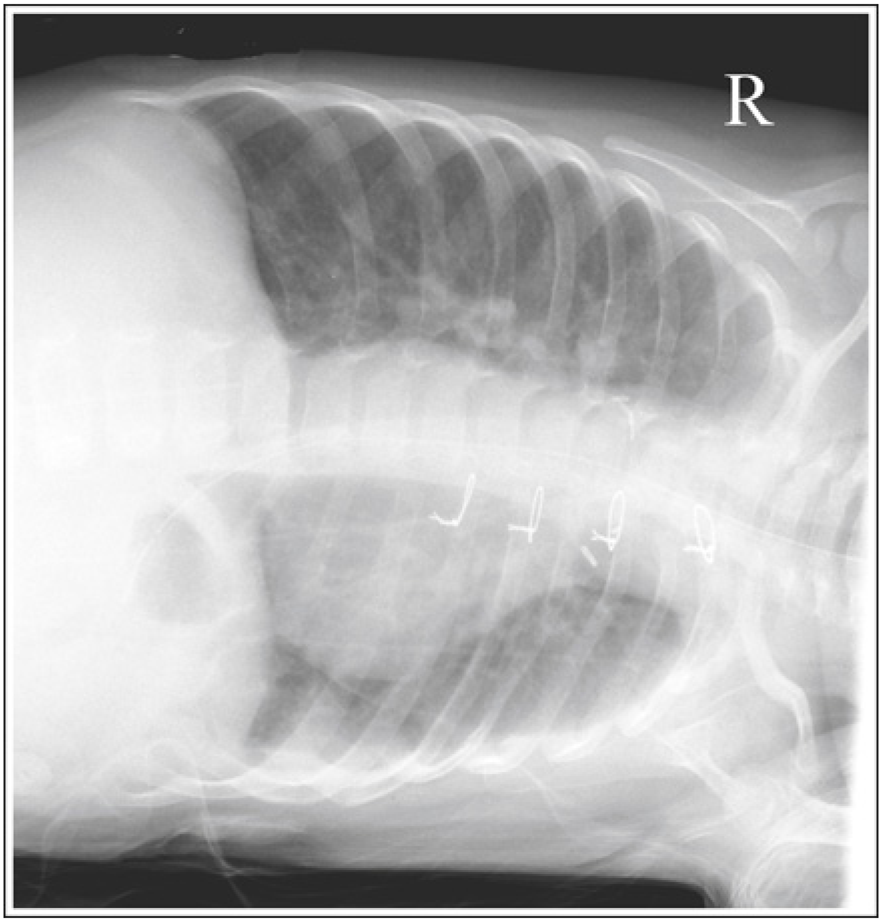


FIGURE 3.105 Neonate AP (left lateral decubitus) chest taken with left side rotated closer to IR than right side, lateral tilting of the midsagittal plane, and the superior midcoronal plane tilted 5 degrees anteriorly.

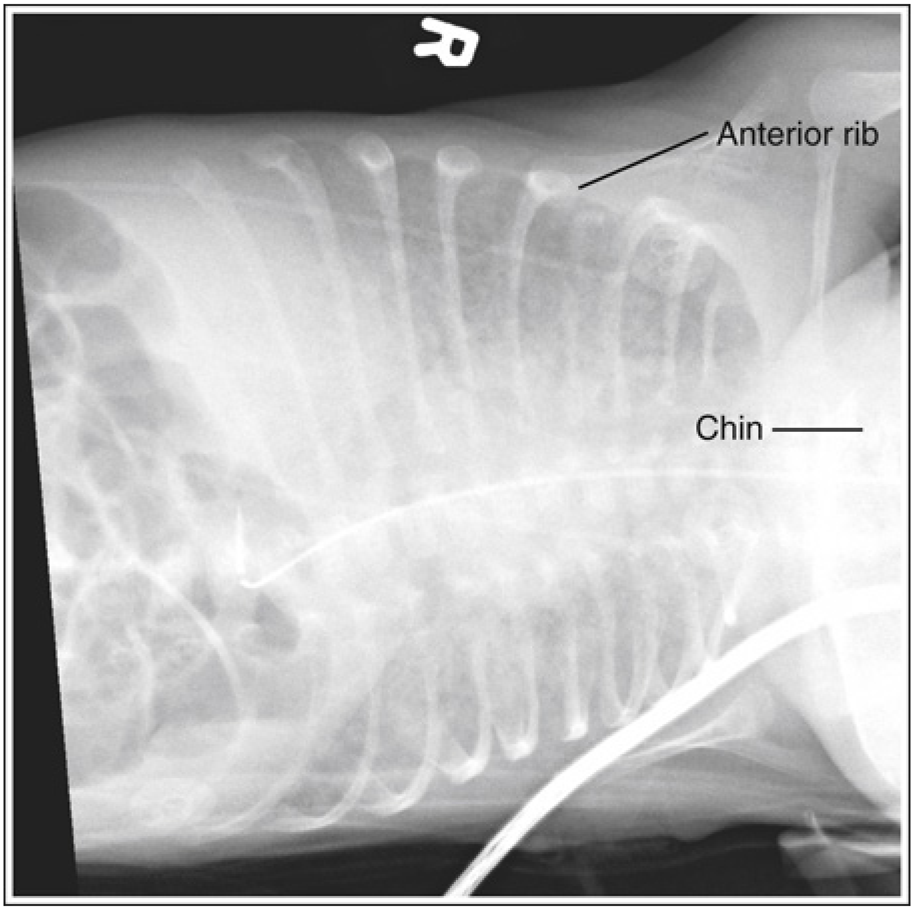


FIGURE 3.106 Neonate AP (left lateral decubitus) chest taken with right side rotated closer to IR than left side and the chin not elevated. Chest has lordotic appearance.

Alternate Patient and IR Alignment

To produce a neonate/infant AP decubitus chest with a reduced lordotic appearance, move the superior midcoronal plane approximately 5 degrees away from the IR, instead of having the upper posterior surface touching the IR. This will create a small OID, but not enough to result in a significant loss of detail sharpness. The CR remains perpendicular to the IR. The resulting projection will place each anterior rib below its corresponding

posterior rib and demonstrate the posterior ribs with a gentle, superiorly bowed contour (Figs. **3.104** and **3.109**). This could also be accomplished by leaving the upper posterior chest against the IR and angling the CR 5 degrees caudally.

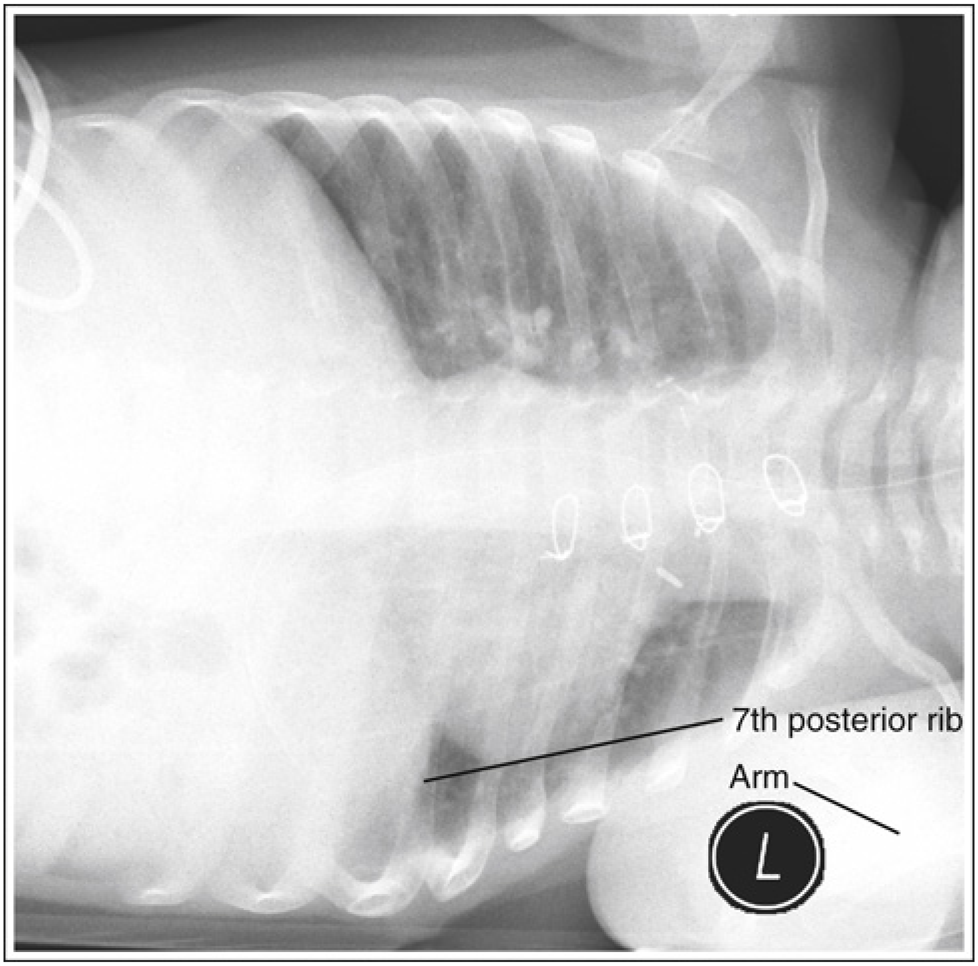


FIGURE 3.107 Neonate AP (left lateral decubitus) chest taken with left arm not elevated.

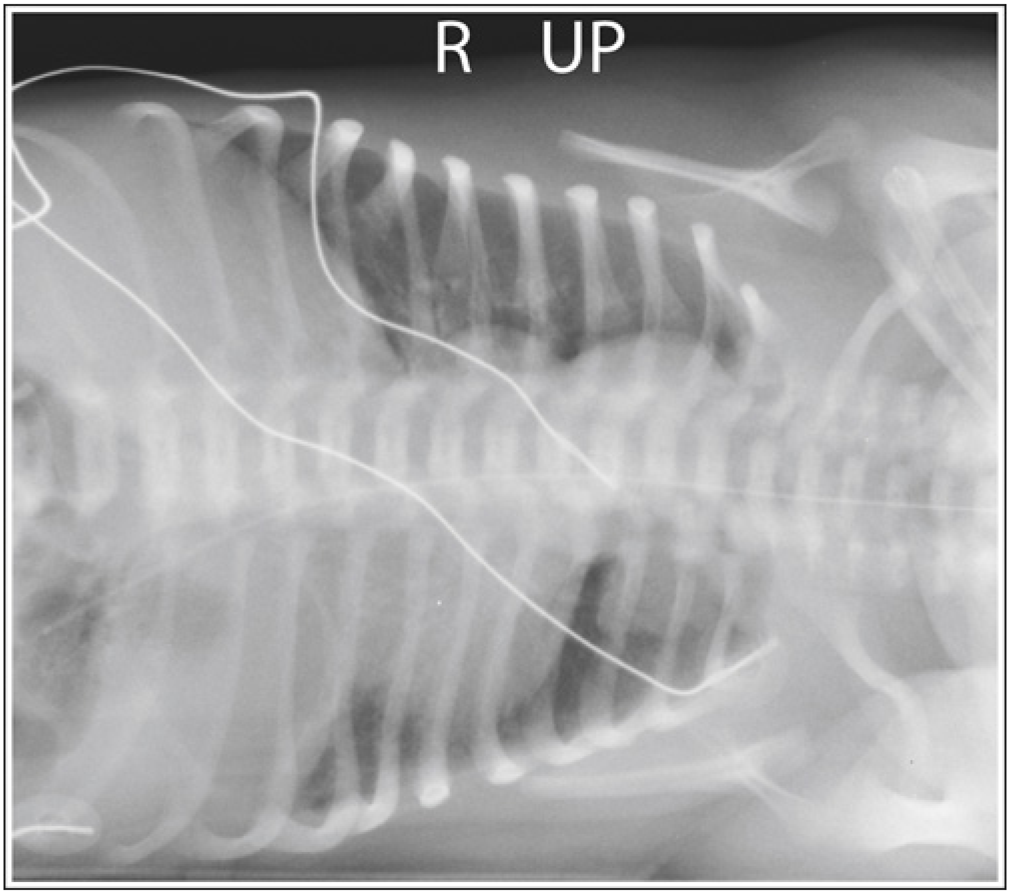


FIGURE 3.108 Neonate AP (left lateral decubitus) chest with lordotic appearance.

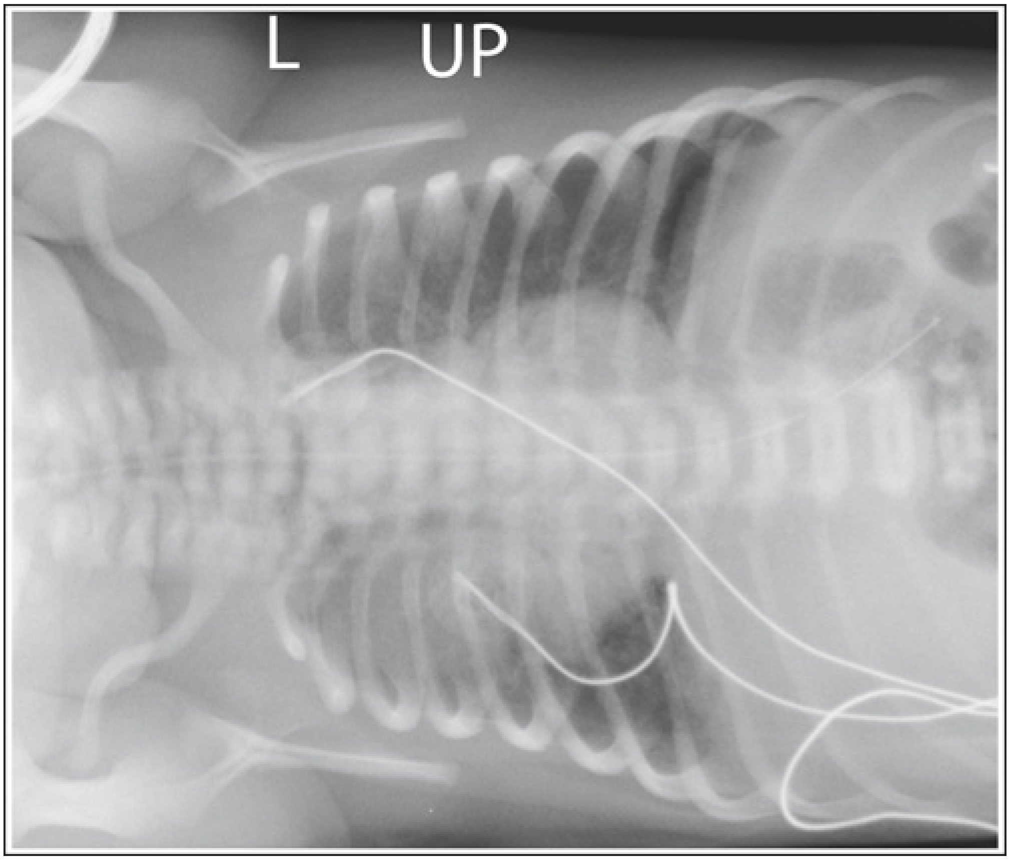


FIGURE 3.109 Neonate AP (right lateral decubitus) chest taken with a 5-degree caudal CR angle.

Neonate and Infant AP Decubitus Chest Analysis Practice

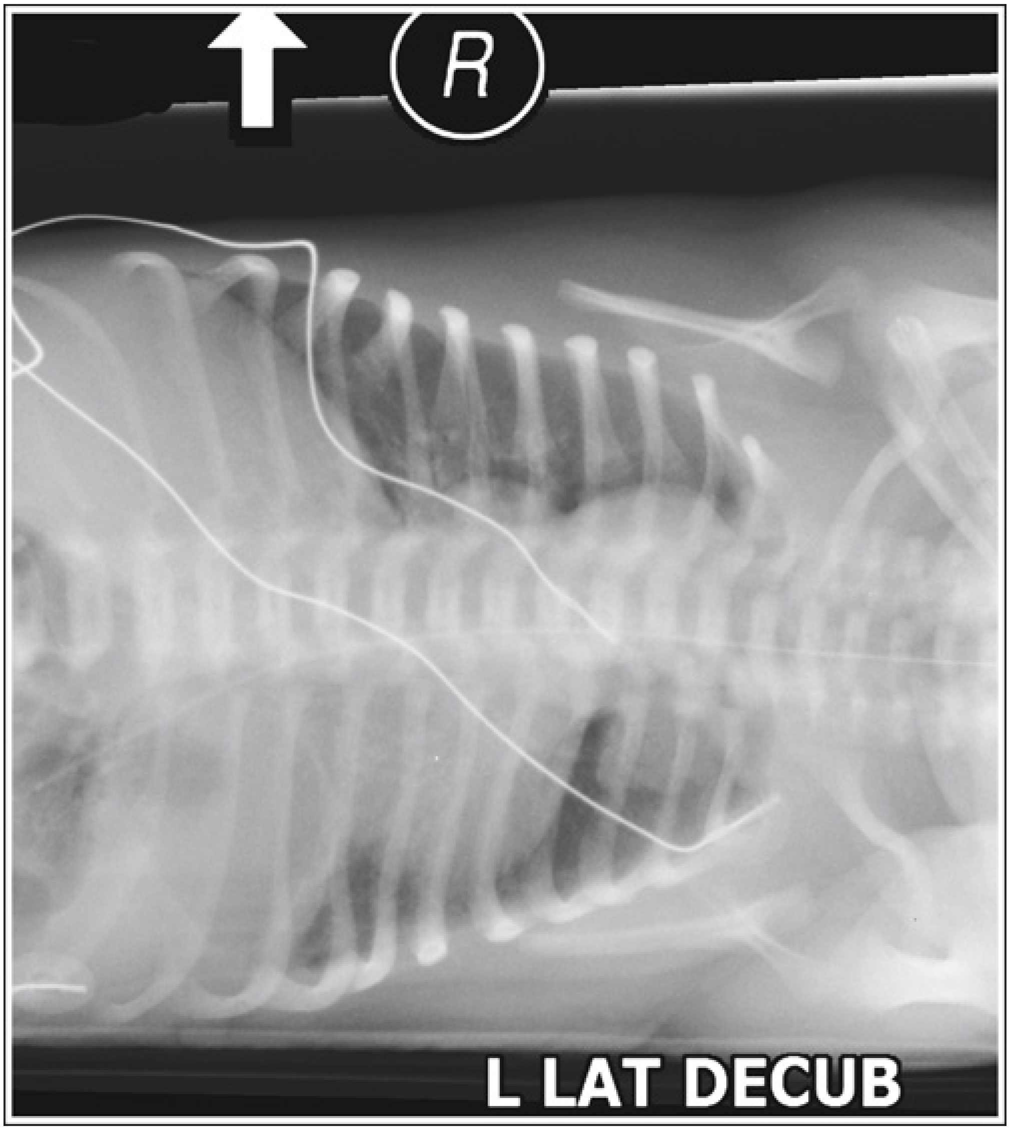


IMAGE 3.27

NEONATE—AP PROJECTION.

Analysis

The chest demonstrates a lordotic appearance. Each upper anterior rib is superior to its corresponding posterior rib, whereas each lower anterior rib

is demonstrated below its corresponding posterior rib. The upper midcoronal plane is too close to the IR, and the CR is centered too inferiorly. The left sternal clavicular end is demonstrated further from the vertebral column than the right, and the left posterior ribs are longer than the right.

Correction

Angle the CR 5 degrees caudally or move the superior chest and shoulders 5 degrees away from the IR. Rotate the left side of the chest away from the IR until the midcoronal plane is parallel with the IR.

Child Chest: AP and PA Projection (Right or Left Lateral Decubitus Position)

See **Table 3.14** and Figs. **3.110** and **3.111**.

The image analysis guidelines for AP/PA decubitus chest projections in children are the same as those of infant or adult AP/PA decubitus chest. The size of the child determines the guidelines that best meet the situation. For a discussion on the topics needed to analyze the following image, refer to the discussion of AP-PA (lateral decubitus) chest projections earlier in this chapter.

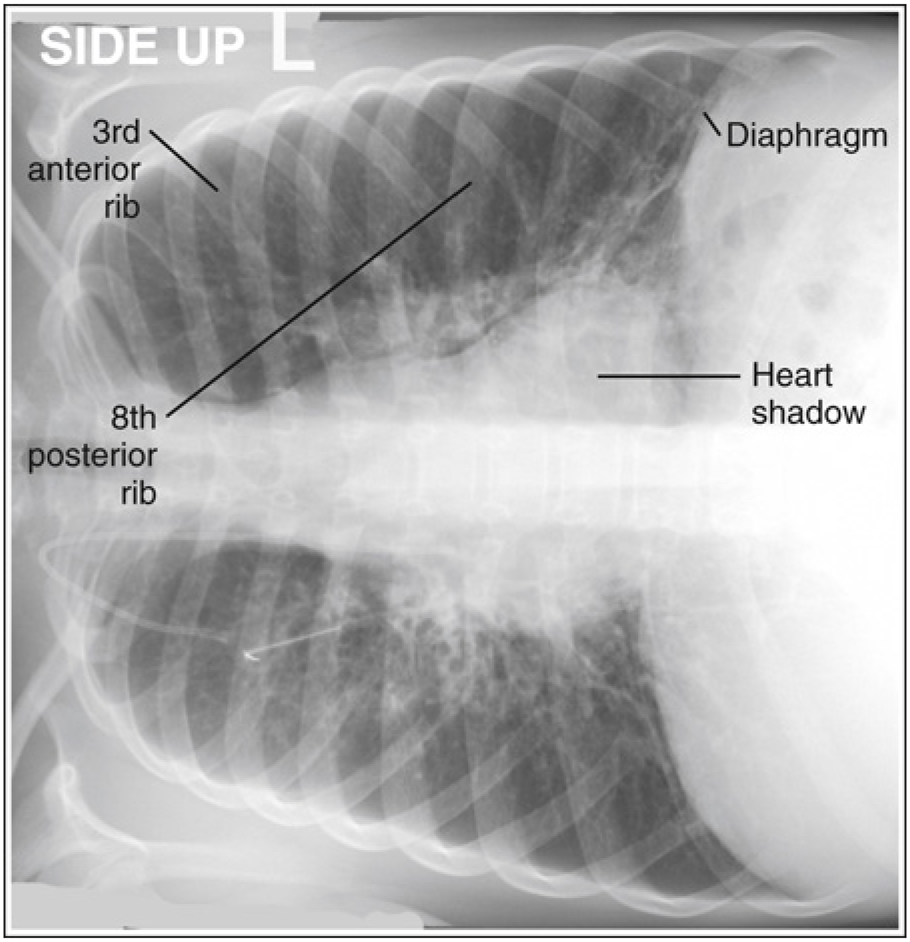


FIGURE 3.110 Child AP (right lateral decubitus) chest projection with accurate positioning.

FIGURE 3.111 Proper patient positioning for an AP (right lateral decubitus) chest projection.

TABLE 3.14

Child AP-PA (Lateral Decubitus) Chest Analysis Practice

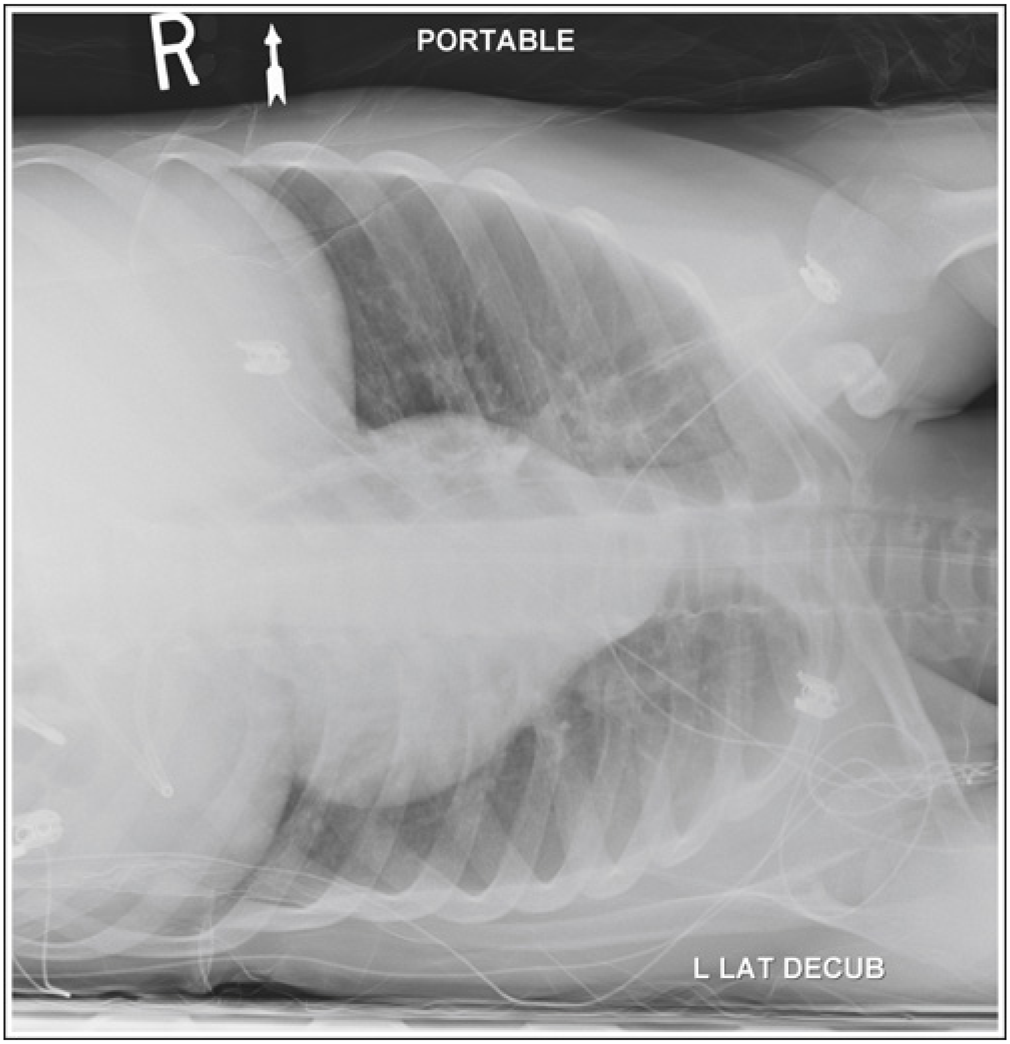


IMAGE 3.28

CHILD.

Analysis

The right sternal clavicular end is situated farther from the vertebral column than the left side, and the posterior ribs on the right side demonstrate the greater length. The patient was rotated toward the right side. The

manubrium is situated at the level of the second thoracic vertebrae. The upper midcoronal plane was tilted toward the IR.

Correction

Rotate the right side away from the IR and tilt the upper thorax away from the IR until the midcoronal plane is parallel with the IR.

Abdomen

Abdomen: AP Projection (Supine and Upright)

See **Table 3.16** and **Figs. 3.118** and **3.119**, and **Table 3.17** and **Figs. 3.120** and **3.121**.

Abdominal Body Habitus

Hypersthenic

The hypersthenic abdomen is broad across the lower thorax from lateral rib to lateral rib, and the torso is short, demonstrating less distance from the lower rib cage to the pubis symphysis in comparison to the other body habitus (**Fig. 3.122**). The widest part of the abdominal cavity is at the upper abdomen as it extends beyond the pelvis on each side.

Asthenic

The asthenic habitus abdomen is generally narrow across the lower thorax, and the torso is long in comparison to the other body types (**Fig. 3.123**). The widest part of the abdominal cavity is at the lower abdomen as the pelvis extends beyond the rib cage on both sides.

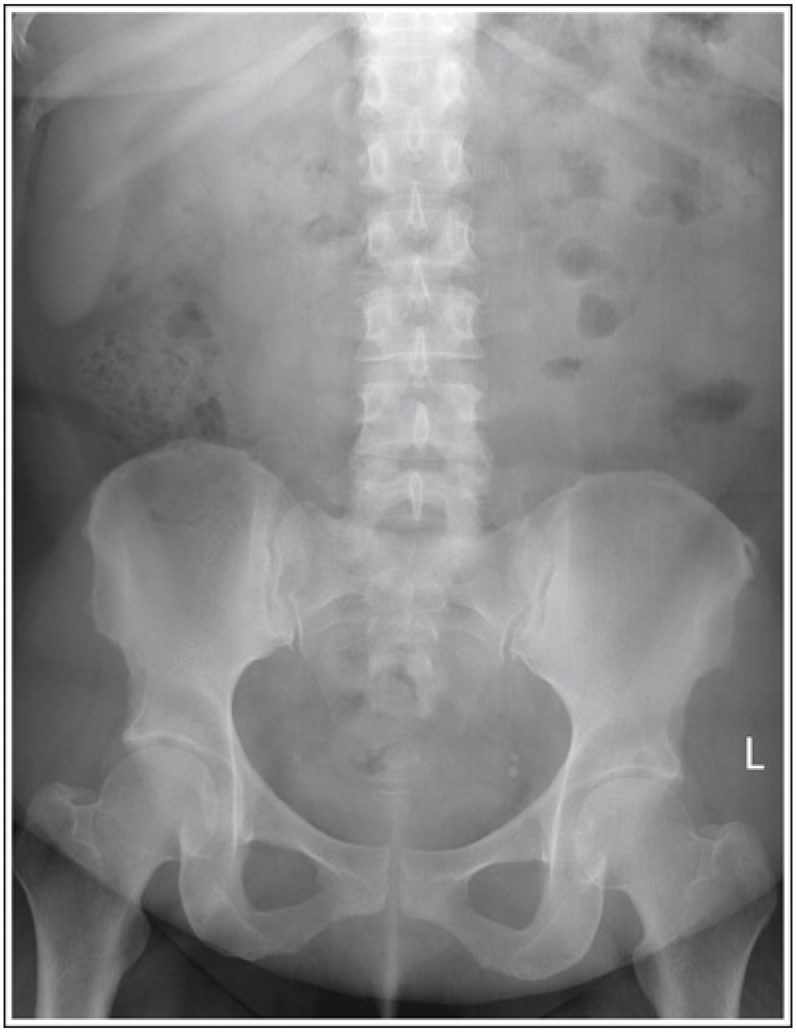


FIGURE 3.117 Supine AP abdomen that does not include all of the required abdominal tissue.

TABLE 3.16

CR, Central ray; *IR*, image receptor; *LW*, lengthwise.

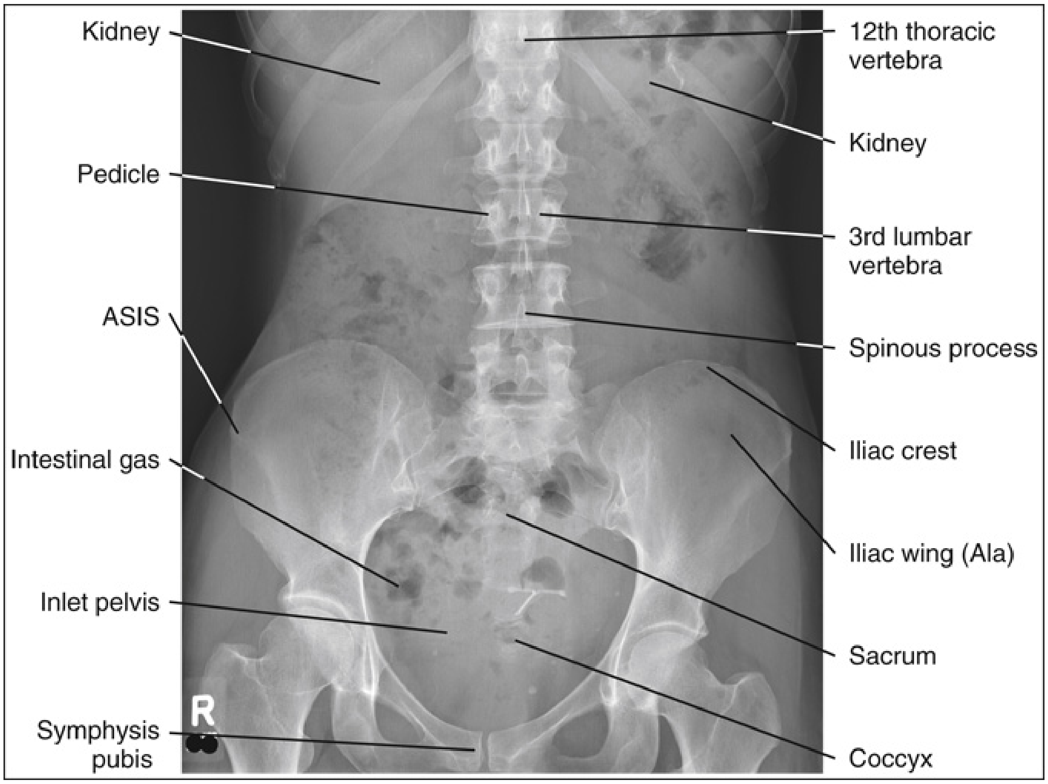


FIGURE 3.118 Supine AP abdomen projection with accurate positioning.

FIGURE 3.119 Proper patient positioning for supine AP abdomen projection.

Sthenic

The sthenic habitus abdomen is the most common, being between the hypersthenic and asthenic body types, and is considered to have the average torso width and length (**Fig. 3.124**). The abdominal cavity is the same width at the upper and lower abdomen, with the rib cage width equaling the pelvis width.

Obese

The obese patient can have the bony architect of any of the above body habitus. In these patients the lower rib cage, and the peritoneal cavity and soft tissue that surrounds it, increases in size outside the bony structures that are used to define these habitus (**Fig. 3.125**).

Body Habitus and Image Receptor Size and Placement Variations

For the supine AP abdomen, including the twelfth thoracic vertebra ensures that the kidneys, tip of the liver, and spleen, all of which lie inferior to it, will be present on the projection. Including the pubis symphysis ensures that the inferior border of the peritoneal cavity is present on the projection (see **Fig. 3.118**). For intraperitoneal air to be demonstrated on the upright AP abdomen, the diaphragm must be included in its entirety, because the air would be located directly inferior to the domes of the diaphragm (see **Fig. 3.116**). When the projection is taken on expiration, including the eighth thoracic vertebra will ensure demonstration of the right and the left diaphragm domes. To include these needed anatomic structures, the number and sizes of IRs that are required, the IR placement, and the CR centering will need to be varied as follows for the differing body habitus and patient sizes.

Supine Hypersthenic Patient

If using the computed radiography system, two 14 × 17 inch (35 × 43 cm) crosswise IRs are needed to include the required anatomic structures, as long as the transverse abdominal measurement is less than 17 inches (43 cm; **Fig. 3.126**). Take the first projection with the CR centered to the midsagittal plane at a level halfway between the pubis symphysis and anterior superior iliac spine (ASIS). Position the bottom of the second IR so

that it includes 2 to 3 inches (5 to 7.5 cm) of the same transverse section of the peritoneal cavity imaged on the first projection to ensure that no middle peritoneal information has been excluded. The top of the IR should extend to the xiphoid, to make sure that the twelfth thoracic vertebra is included.

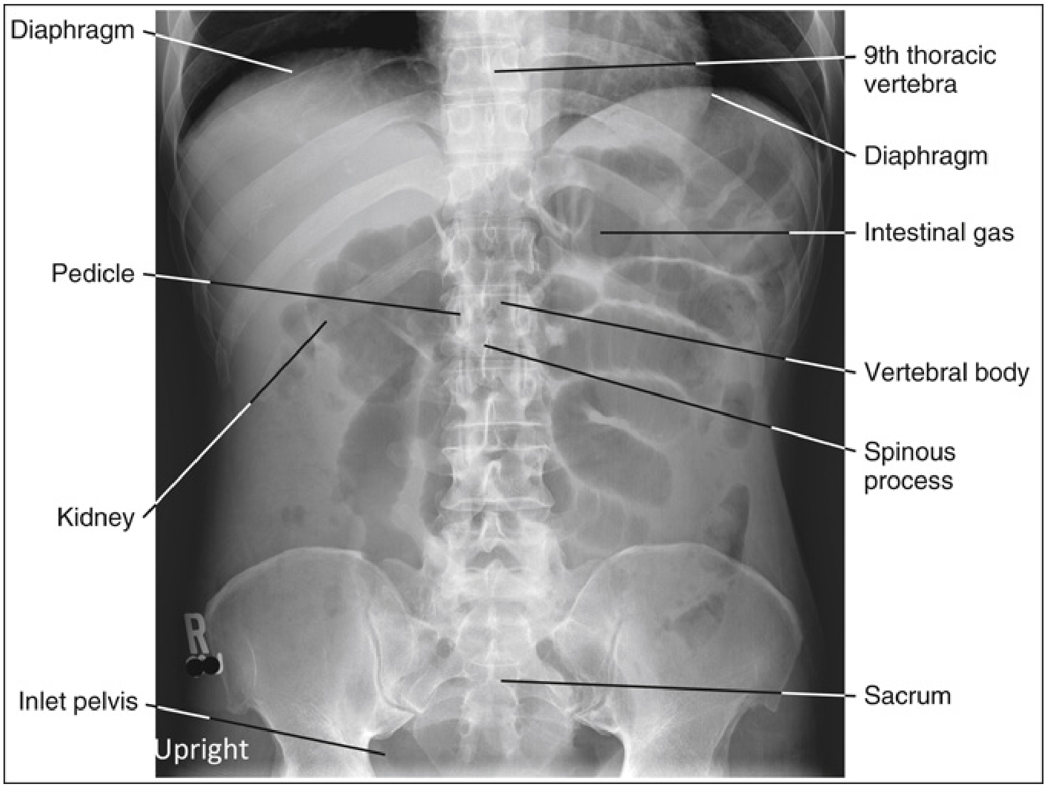


FIGURE 3.120 Upright AP abdomen projection with accurate positioning.

TABLE 3.17

CR, Central ray; *IR*, image receptor; *LW*, lengthwise.

If using the DR system, open the longitudinal collimation the full 17 inches (43 cm) and transversely collimate to within 0.5 inches (2.5 cm) of the lateral skin lines as needed to the full 17 inches (43 cm) available. If more than 17 inches (43 cm) of transverse width is needed for either of these systems, use the following obese procedure.

Upright Hypersthenic Patient

Follow the same general procedure explained for the supine hypersthenic patient, with the exception that the first projection is taken with the top of the IR positioned just a bit higher than the axilla and the second projection includes 2 to 3 inches (5 to 7.5 cm) of the same transverse section of the peritoneal cavity imaged on the first projection.

Supine Obese Patient

It may be necessary to obtain three or four images to demonstrate all of the abdominal structures for the obese patient. **Fig. 3.125** demonstrates a supine AP abdomen procedure on an obese patient that required three projections to include all of the required abdominal tissue. If using the computed radiography system, take the first projection with the IR crosswise and the CR centered to the midsagittal plane at a level halfway between the pubis symphysis and ASIS. To obtain the second projection, place the IR lengthwise and positioned so the bottom of the IR includes 2 to 3 inches (5 to 7.5 cm) of the same transverse section of peritoneal cavity imaged on the first projection, center the CR to the IR, and then move the patient (and imaging tabletop) laterally until the CR is centered on the right side halfway between the midsagittal plane and lateral soft tissue. For the third projection, repeat the procedure for the left side of the patient. The second and third projections should include 2 to 3 inches (5 to 7.5 cm) of overlapping peritoneal tissue at the midsagittal plane.

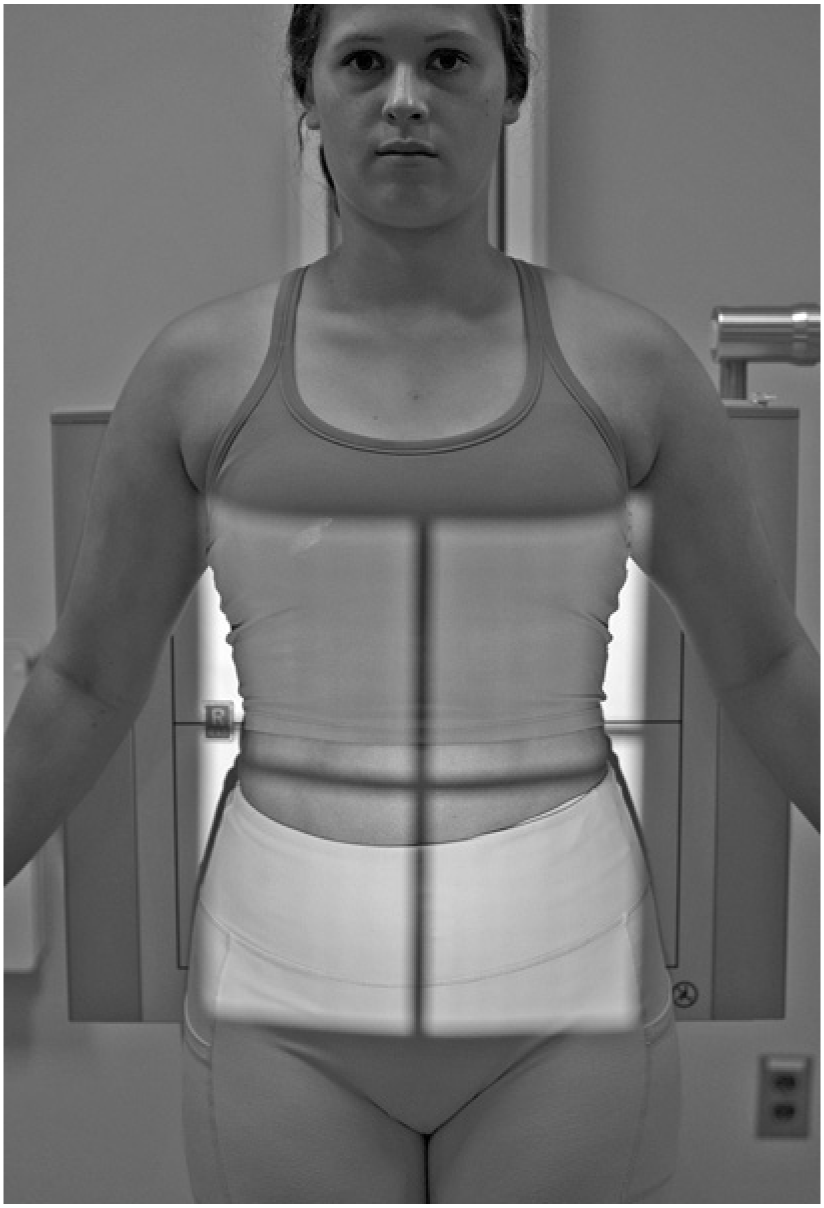


FIGURE 3.121 Proper patient positioning for upright AP abdomen projection.

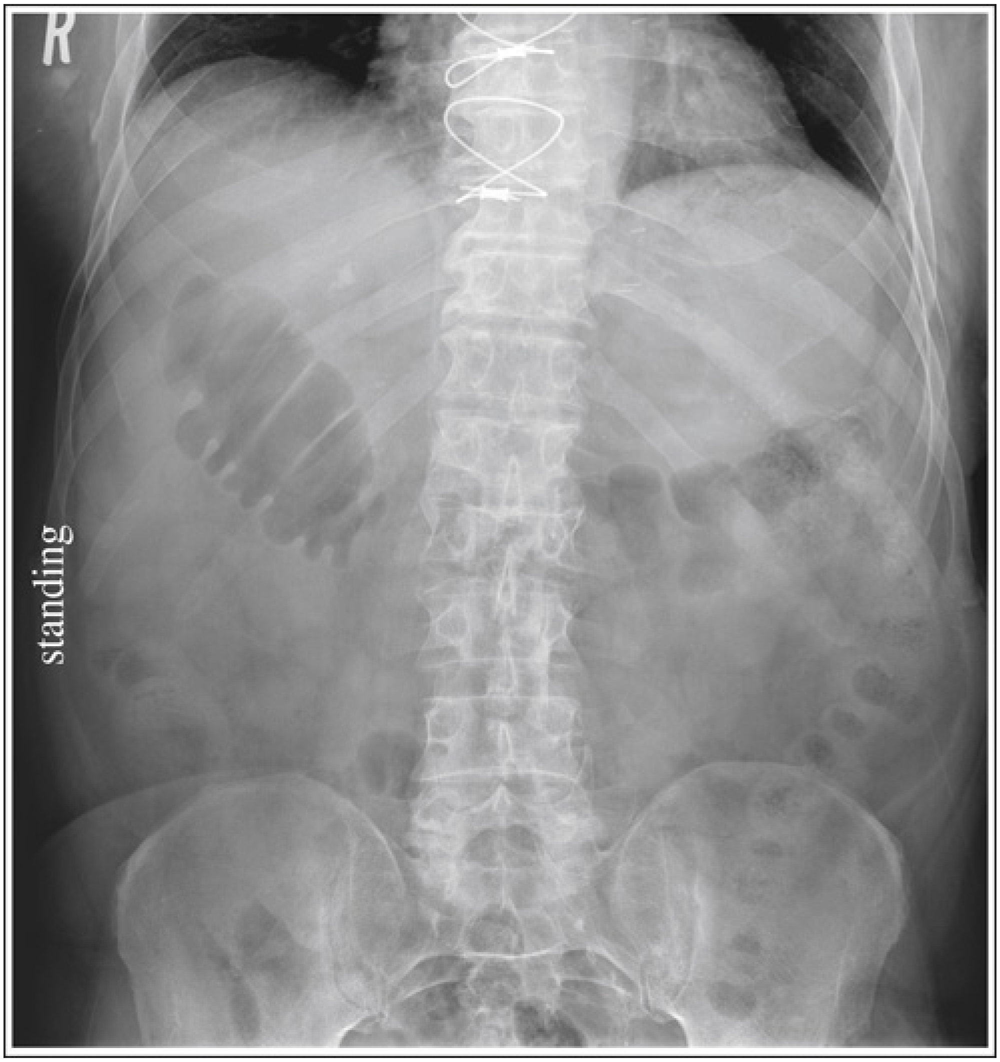


FIGURE 3.122 Upright AP abdomen on hypersthenic patient.

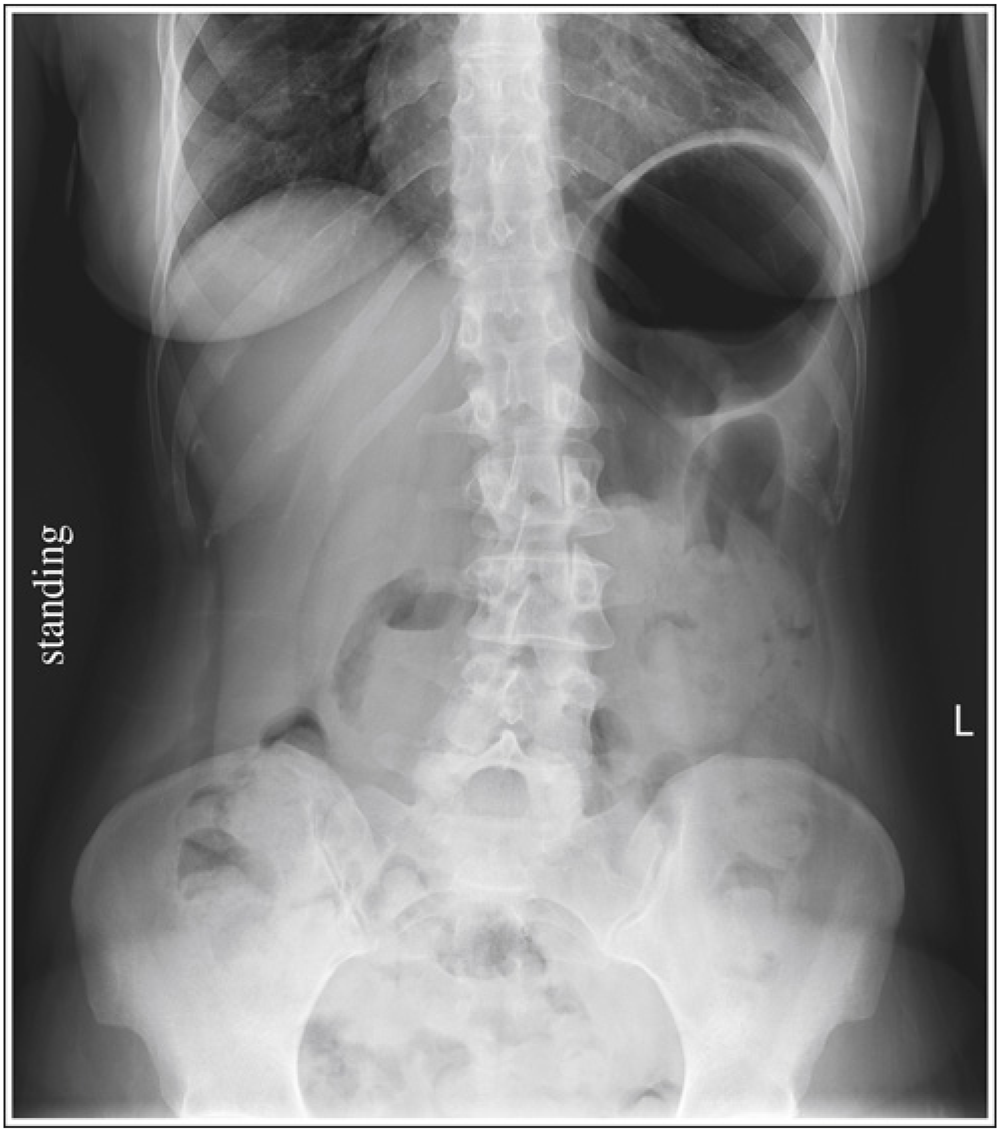


FIGURE 3.123 Upright AP abdomen on asthenic patient.

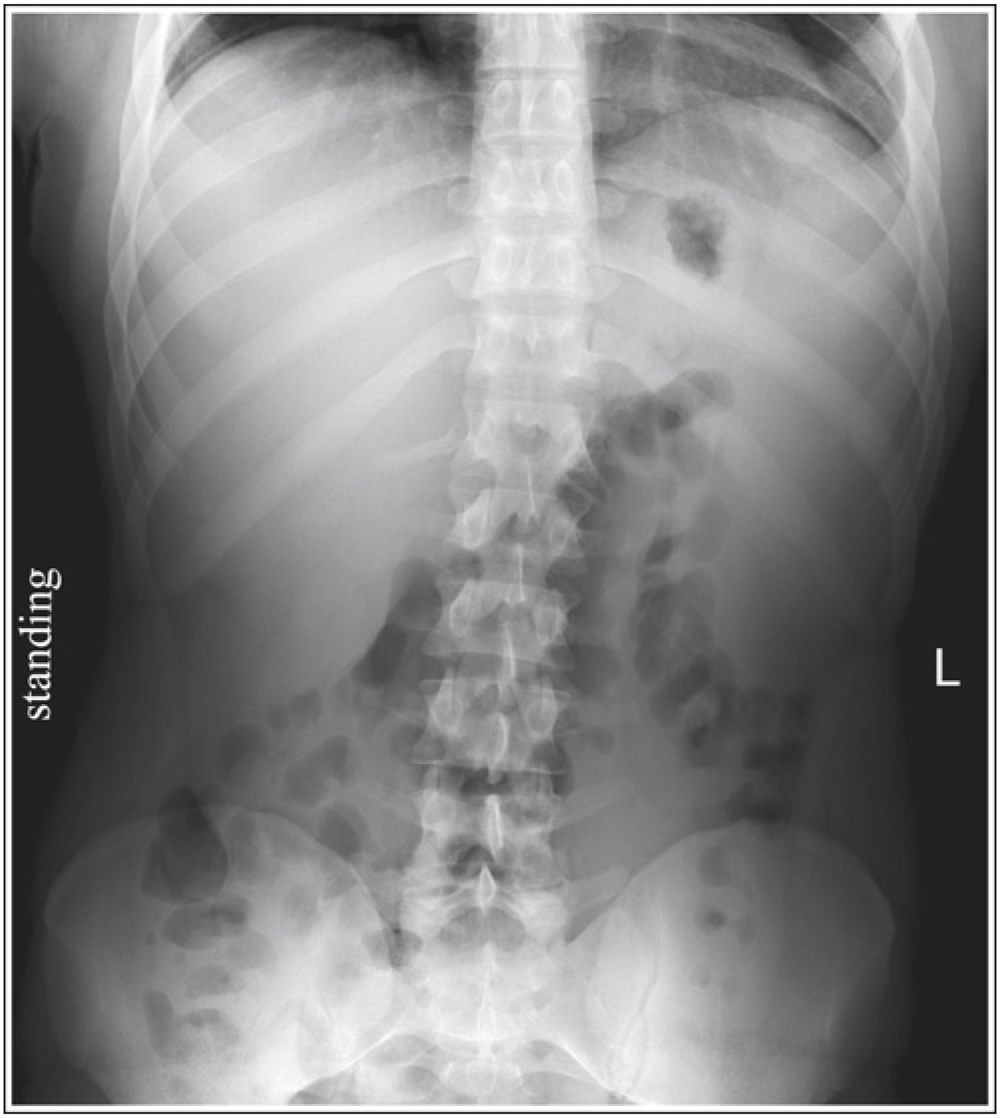


FIGURE 3.124 Upright AP abdomen on a sthenic patient.

If using the DR system, follow that used for the computed radiography system, with the exception that collimation will need to be increased below the full 17 inches (43 cm) for the projections or more than 2 to 3 inches (5 to 7.5 cm) of overlap will result.

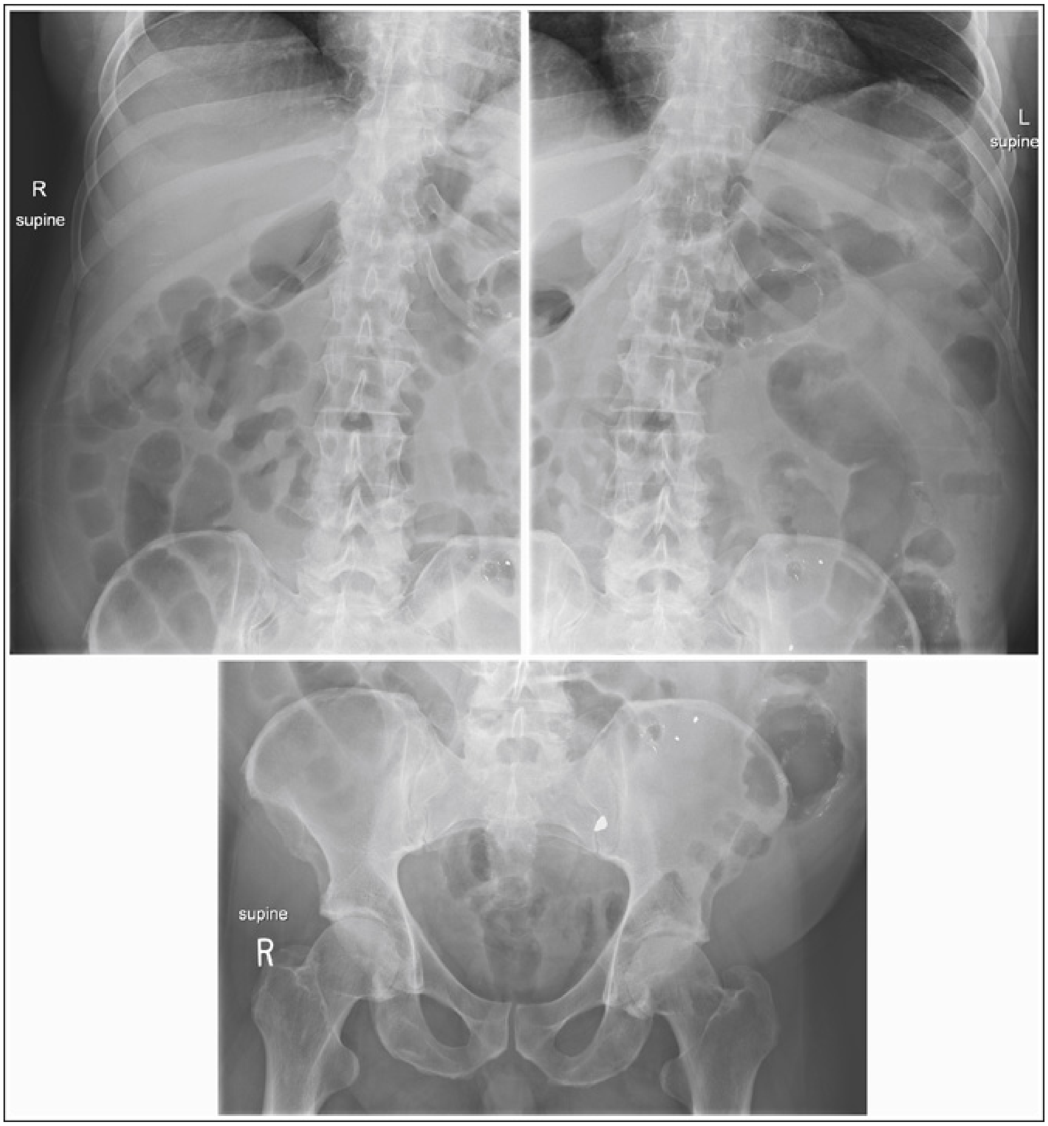


FIGURE 3.125 Supine AP abdomen on obese patient taken using two lengthwise and one crosswise IR cassettes.

Upright: Obese Patient

Follow the same general procedure explained for the supine obese patient, with the exception that the two lengthwise projections should be obtained first, with the top of the IRs positioned at the axilla, and then the third crosswise projection is obtained of the lower peritoneal cavity. Each

projection should include 2 to 3 inches (5 to 7.5 cm) of the same tissue that is included in the adjacent projection.

Abdomen Rotation

Failing to position the midcoronal plane parallel with the IR for an AP abdomen decreases the visualization of fat lines that surround abdominal structures. For example, the psoas major muscles are outlined on the projection because of the fat that lies next to them. When the patient is rotated to one side, this fat shifts from lateral to anterior or posterior with respect to the muscle. The shift eliminates the subject contrast difference that exists when the muscle and fat are separated, hindering the usefulness of the psoas major muscles as diagnostic indicators.

Since the upper and lower lumbar vertebrae can demonstrate rotation independently or simultaneously, depending on which section of the body is rotated, the entire lumbar spine should be evaluated for rotation. To detect rotation on an AP abdomen projection, compare the distance from the pedicles to the spinous processes on each side and the widths of the iliac wings, and evaluate the centering of the sacrum within the inlet pelvis. If the distance from the pedicles to the spinous processes is greater on one side of the vertebrae than on the other, one iliac wing is narrower than the other, or if the sacrum is rotated toward one side of the inlet, pelvic rotation is present (Figs. **3.127** and **3.128**). The side with the smaller distance between the pedicles and spinous processes, the narrower iliac wing, and the side toward which the sacrum is rotated is the side of the patient positioned farther from the imaging table and IR.

Distinguishing Abdominal Rotation From Scoliosis

In patients with scoliosis, the lumbar bodies may appear rotated because of the lateral twisting of the vertebrae. Scoliosis of the vertebral column can be

very severe, demonstrating a large degree of lateral deviation, or it can be subtle, demonstrating only a small degree of deviation. Severe scoliosis is very obvious and is seldom mistaken for patient rotation, whereas subtle scoliotic changes can be easily mistaken for patient rotation (Figs. **3.129** and **3.130**). Although both demonstrate unequal distances between the pedicles and spinous processes, clues that can be used to distinguish subtle scoliosis from rotation are present. The long axis of a rotated vertebral column remains straight, whereas the scoliotic vertebral column demonstrates lateral deviation. When the lumbar vertebrae demonstrate rotation, it has been caused by the rotation of the upper or lower torso. The middle lumbar vertebrae (L3 and L4) cannot rotate unless the lower thoracic vertebrae or upper or lower lumbar vertebrae are also rotated. On the scoliotic projection, the middle lumbar vertebrae may demonstrate rotation without corresponding upper or lower vertebral rotation. This constitutes an acceptable projection for a patient with this condition.

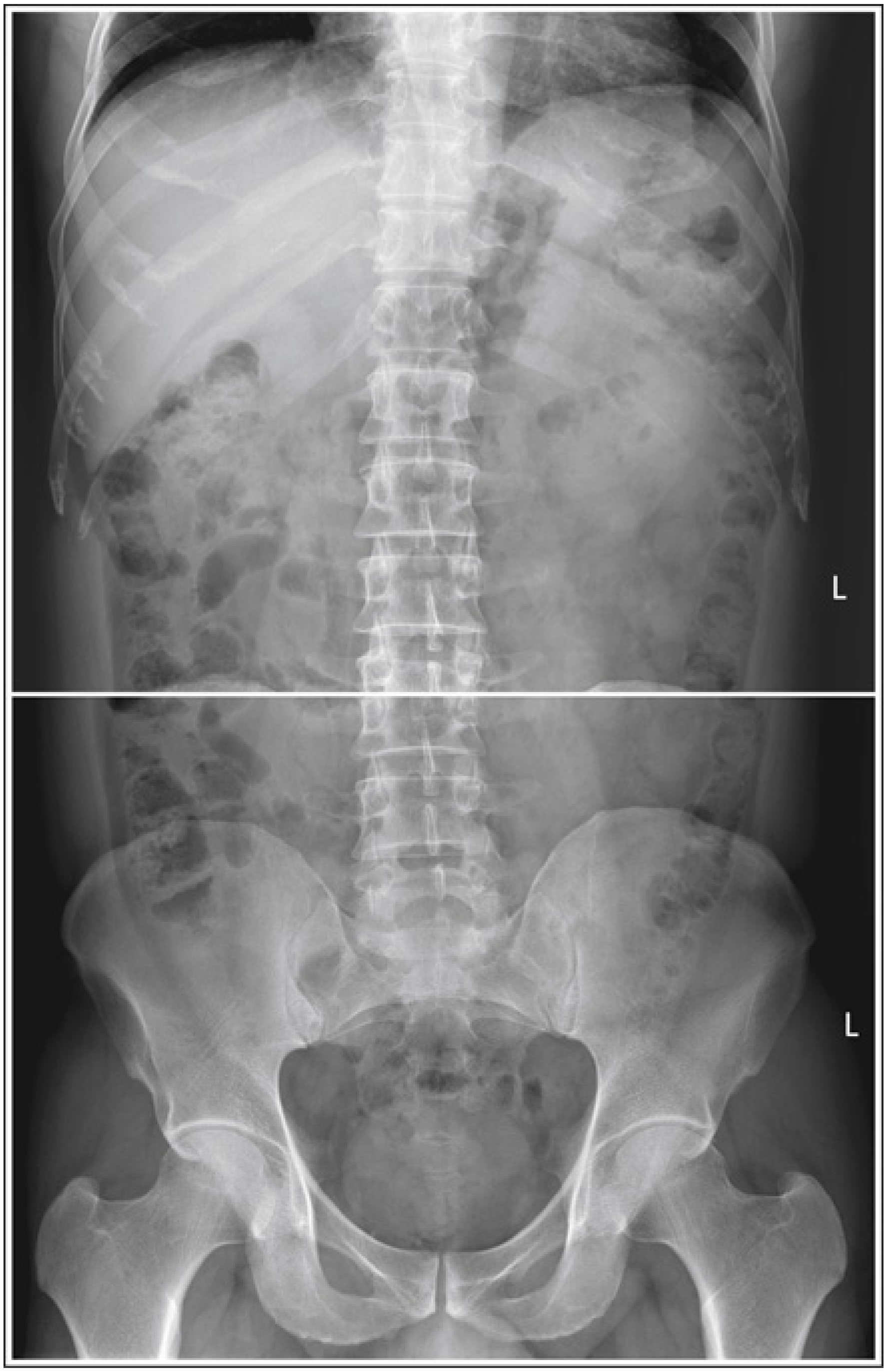


FIGURE 3.126 Supine AP abdomen on hypersthenic patient taken using two crosswise projections

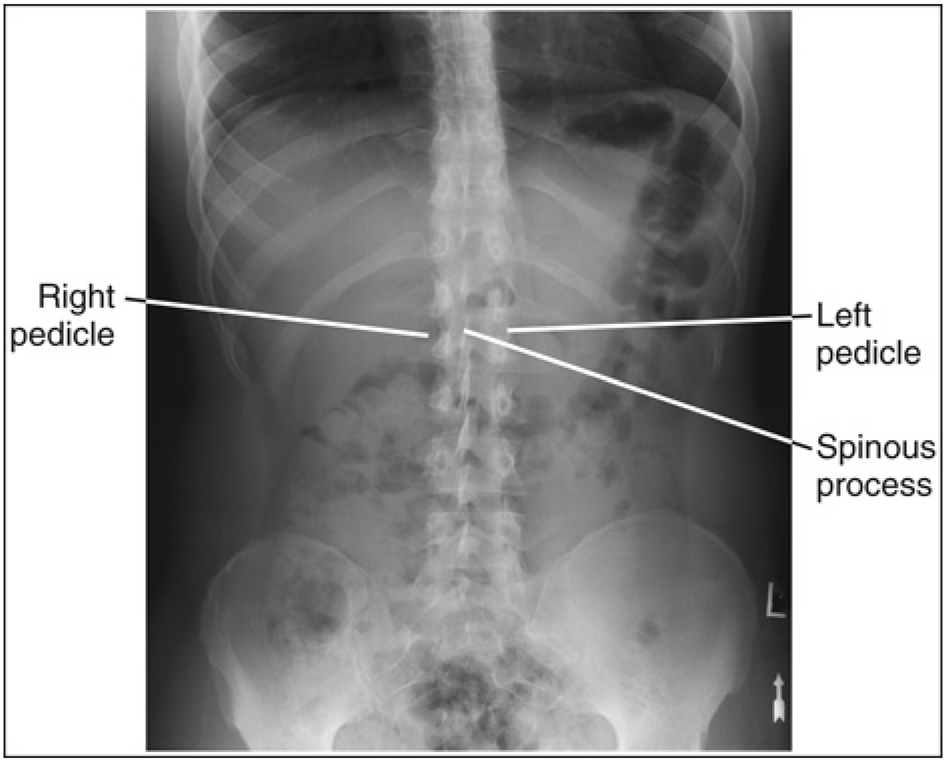


FIGURE 3.127 Upright AP abdomen taken with the left side of abdomen rotated closer to IR than right side (LPO position).

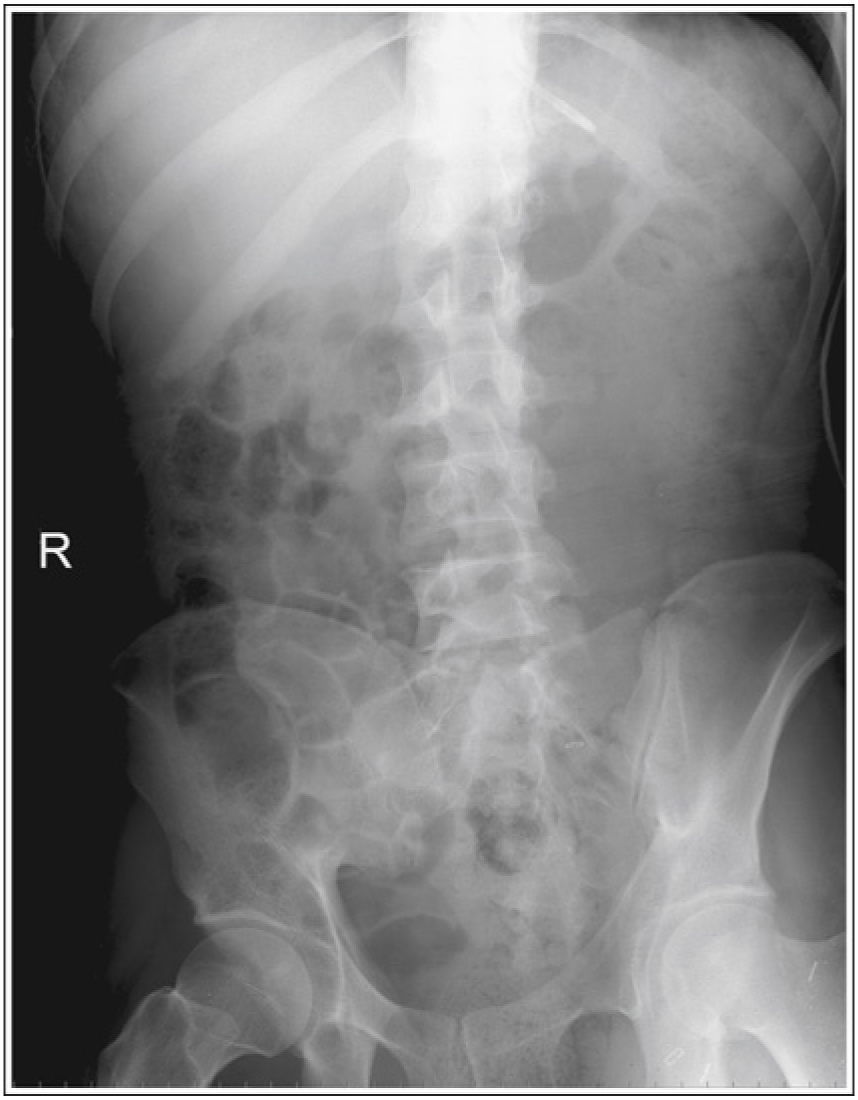


FIGURE 3.128 Supine AP abdomen taken with the right side of abdomen rotated closer to IR than left side (RPO position).

FIGURE 3.129 Supine AP abdomen taken on patient with scoliosis.

Respiration

From full inspiration to expiration, the diaphragm position moves in the vertical dimension as much as 4 inches (10 cm). This movement also changes the pressure placed on the abdominal structures. On full expiration, the right side of the diaphragm dome is at the same transverse level as the eighth or ninth thoracic vertebra, whereas on inspiration, it may be found at a transverse level as low as the twelfth thoracic vertebra (**Fig. 3.131**). Expiration is preferred for AP abdominal projections, because it places less

diaphragm pressure on the abdominal organs, resulting in more space in the peritoneal cavity and less abdominal density.

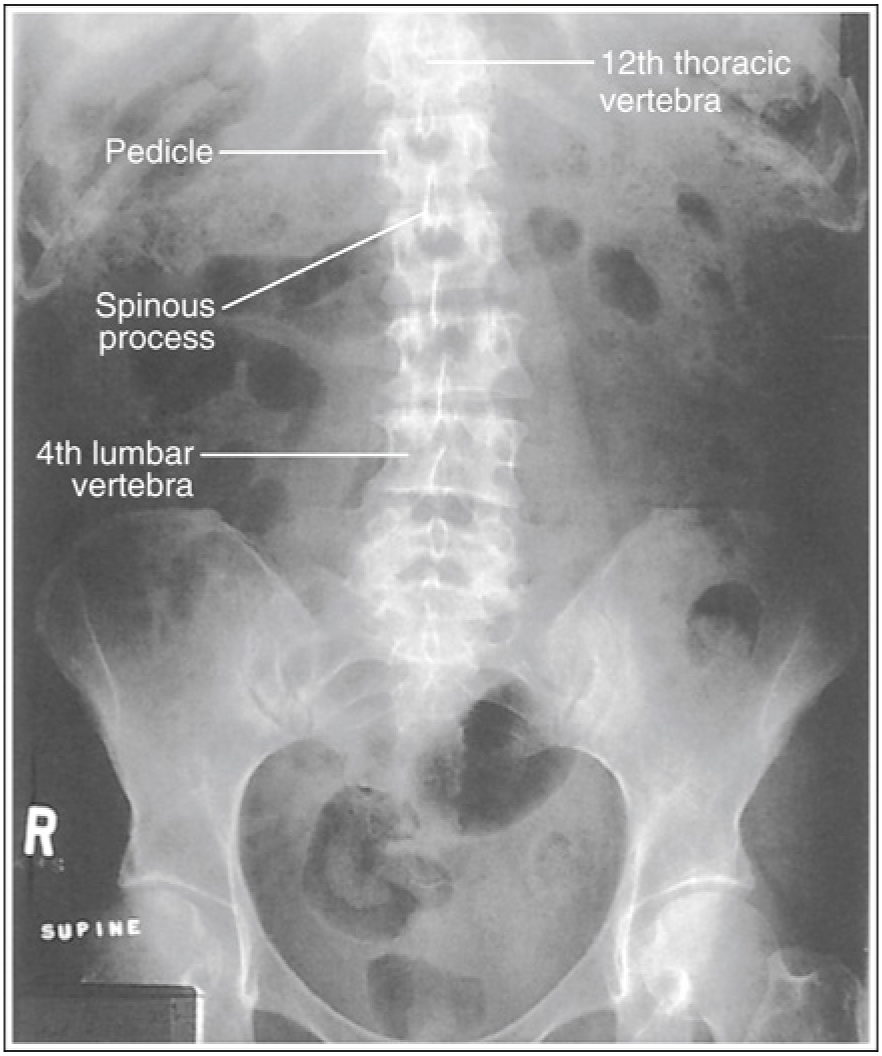


FIGURE 3.130 Supine AP abdomen taken on patient with subtle scoliosis.

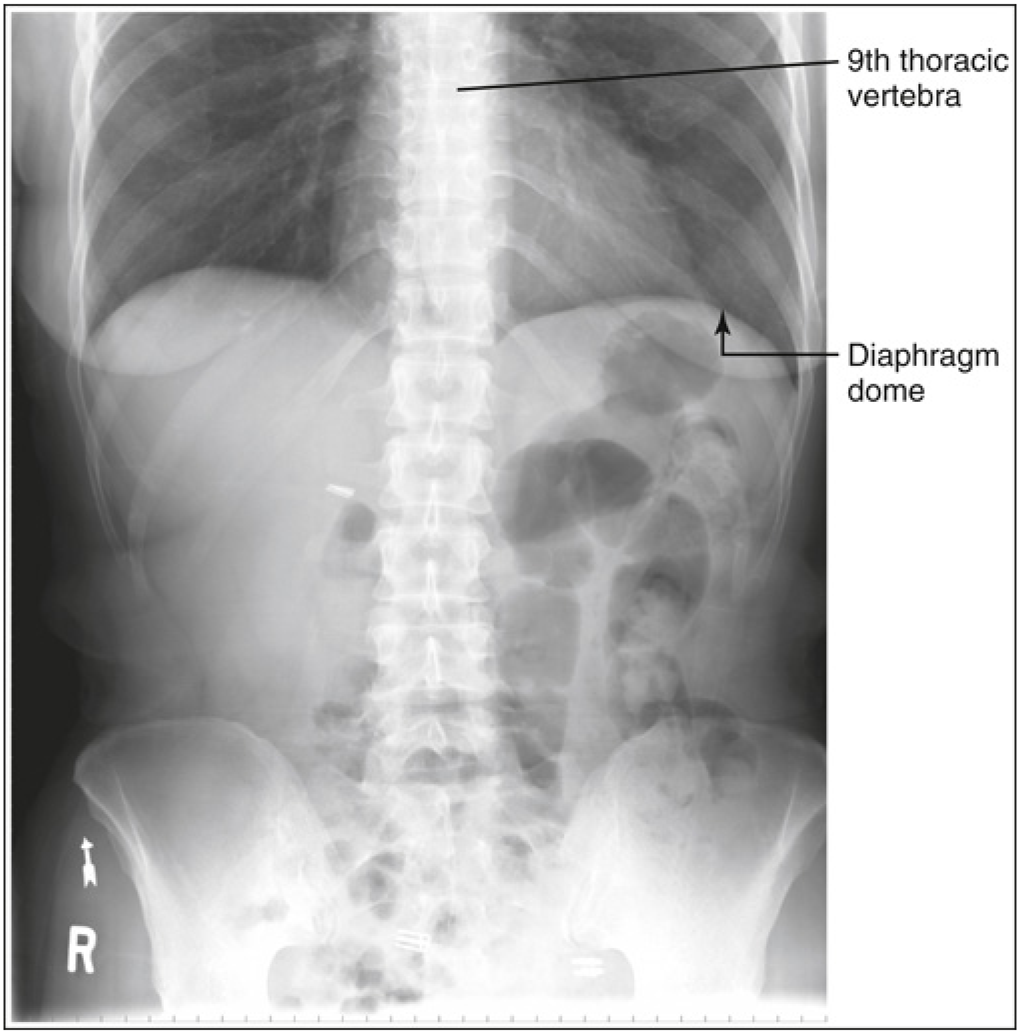


FIGURE 3.131 Upright AP abdomen taken after full inspiration.

AEC Chamber Choice and Respiration

Quantum mottle may also result in AP upper projections that are obtained with full inspiration when the three AEC chambers are chosen, because the outside AEC chambers will be positioned fully or partially beneath the lungs instead of abdominal structures (**Fig. 3.132**).

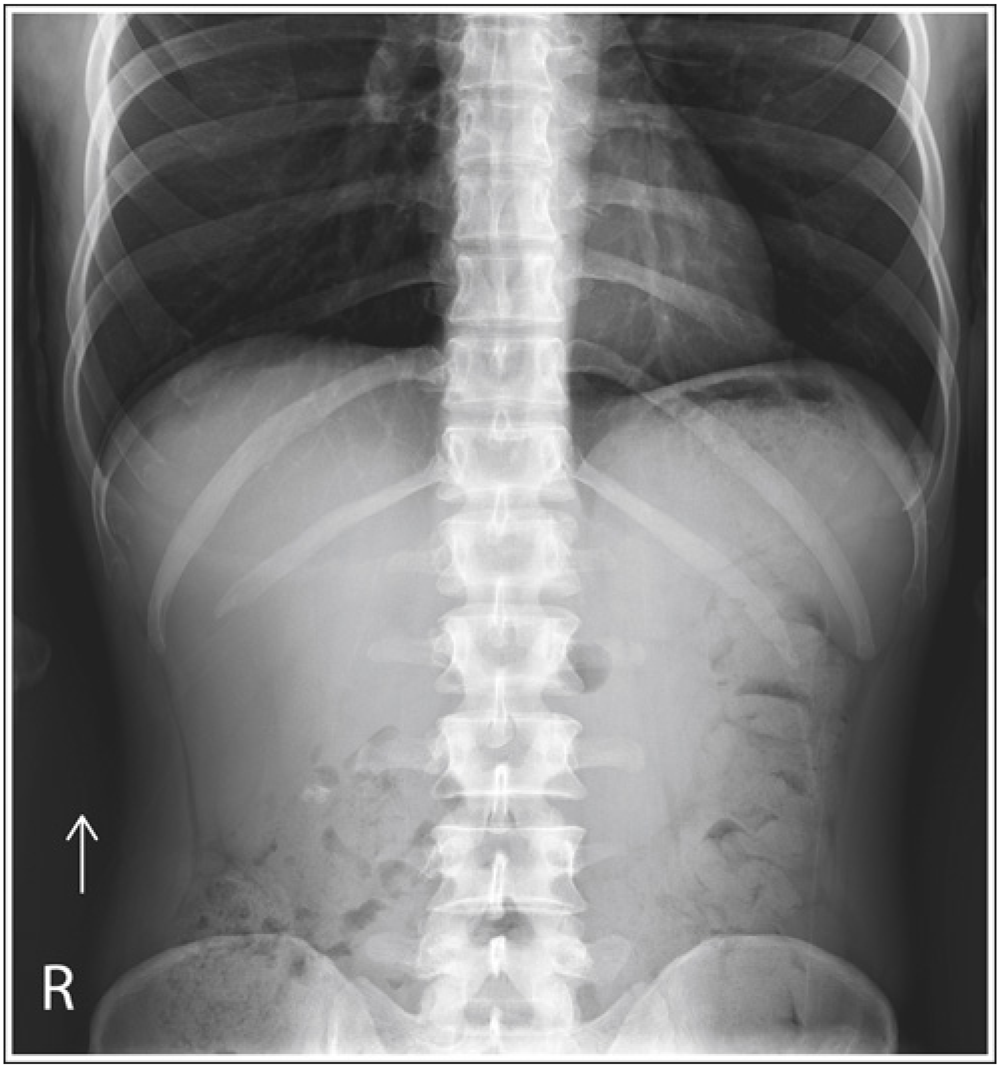


FIGURE 3.132 Upright AP abdomen taken using the two outside AEC chambers and after full inspiration.

AP Abdomen Analysis Practice

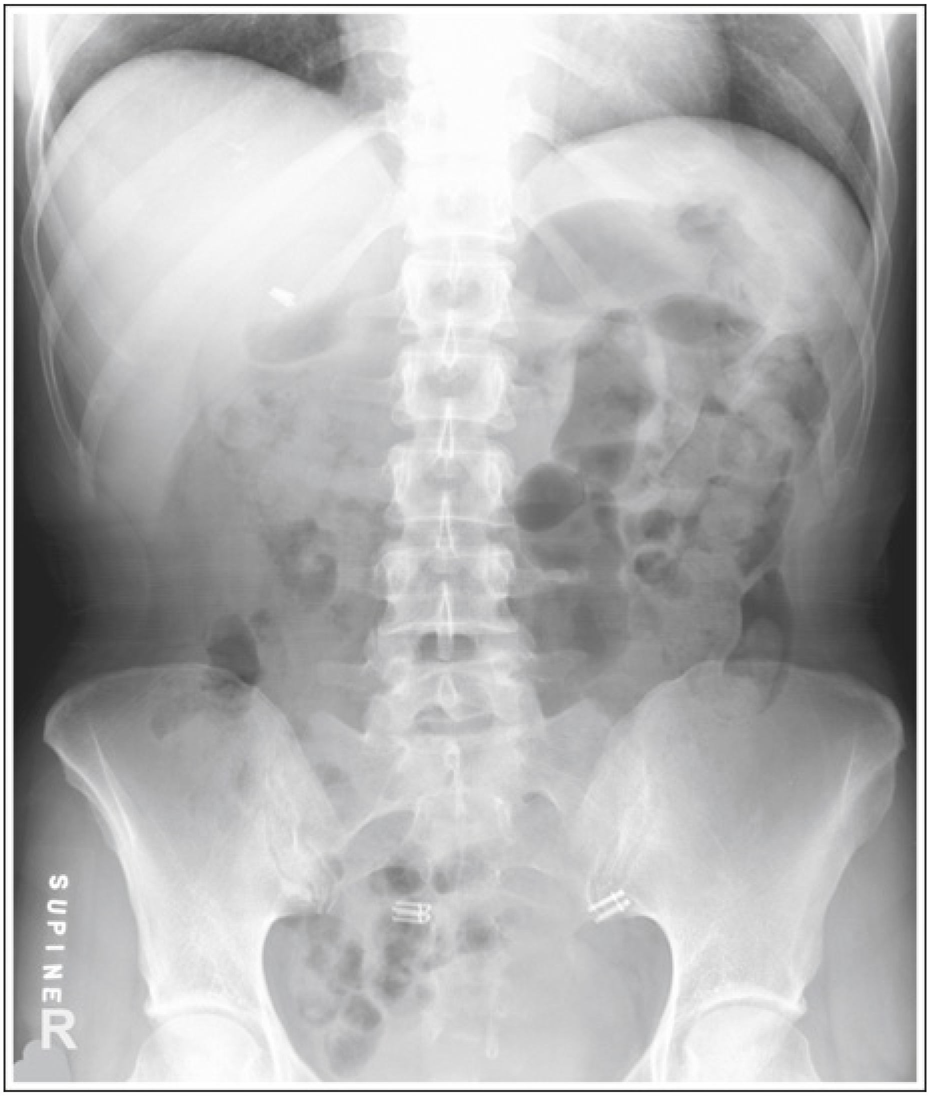


IMAGE 3.29

SUPINE ABDOMEN.

Analysis

The pubis symphysis is not included on the projection. The CR was centered too superiorly.

Correction

Because this is a male patient, center the CR 1 inch (2.5 cm) inferior to the iliac crest.

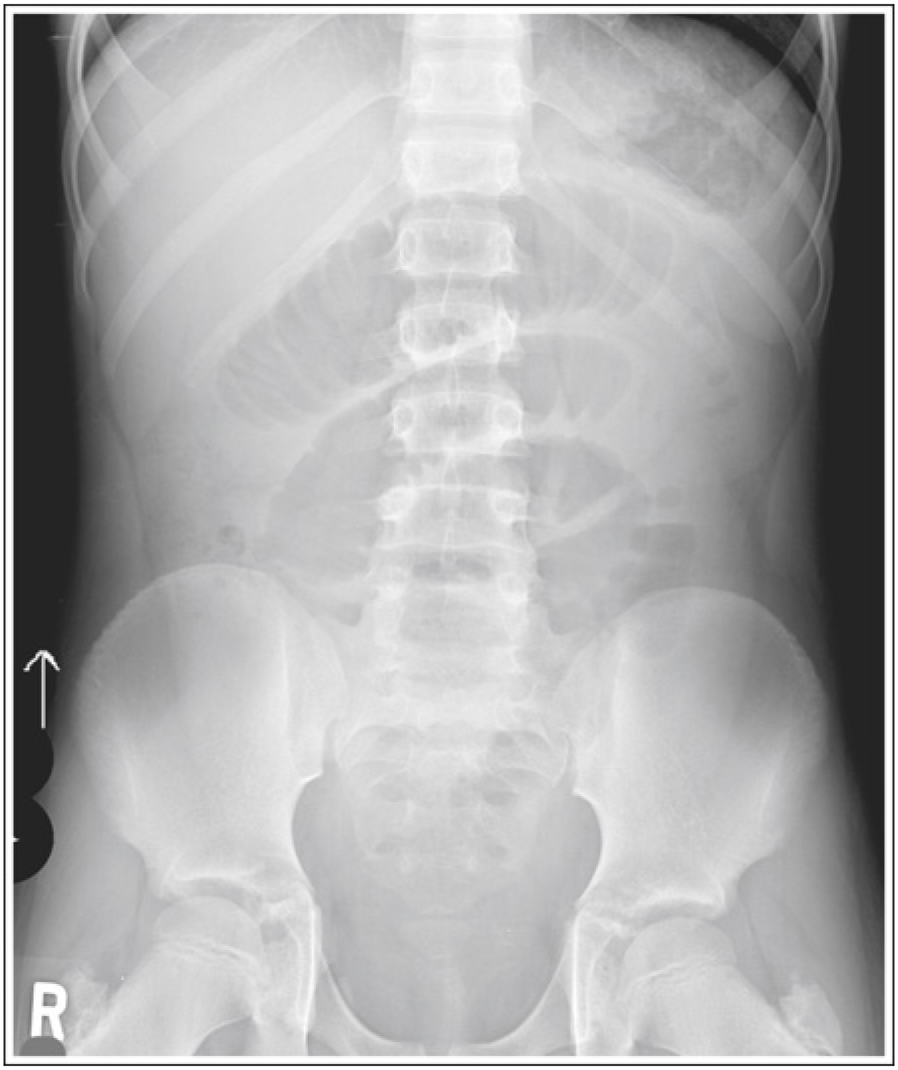


IMAGE 3.30

UPRIGHT AP ABDOMEN.

Analysis

The domes of the diaphragm are not included on the projection. The CR was centered too inferiorly.

Correction

Center the CR and IR approximately 2 inches (5 cm) superiorly.

IMAGE 3.31

UPRIGHT AP ABDOMEN.

Analysis

The diaphragm is at the level of the eleventh thoracic vertebra. The projection was taken on inspiration. The lumbar vertebrae demonstrate subtle scoliosis.

Correction

Take the exposure after full expiration.

Abdomen: AP Projection (Left Lateral Decubitus Position)

See **Table 3.18** and **Figs. 3.133** and **3.134**.

TABLE 3.18

CR, Central ray; *IR*, image receptor; *LW*, lengthwise.

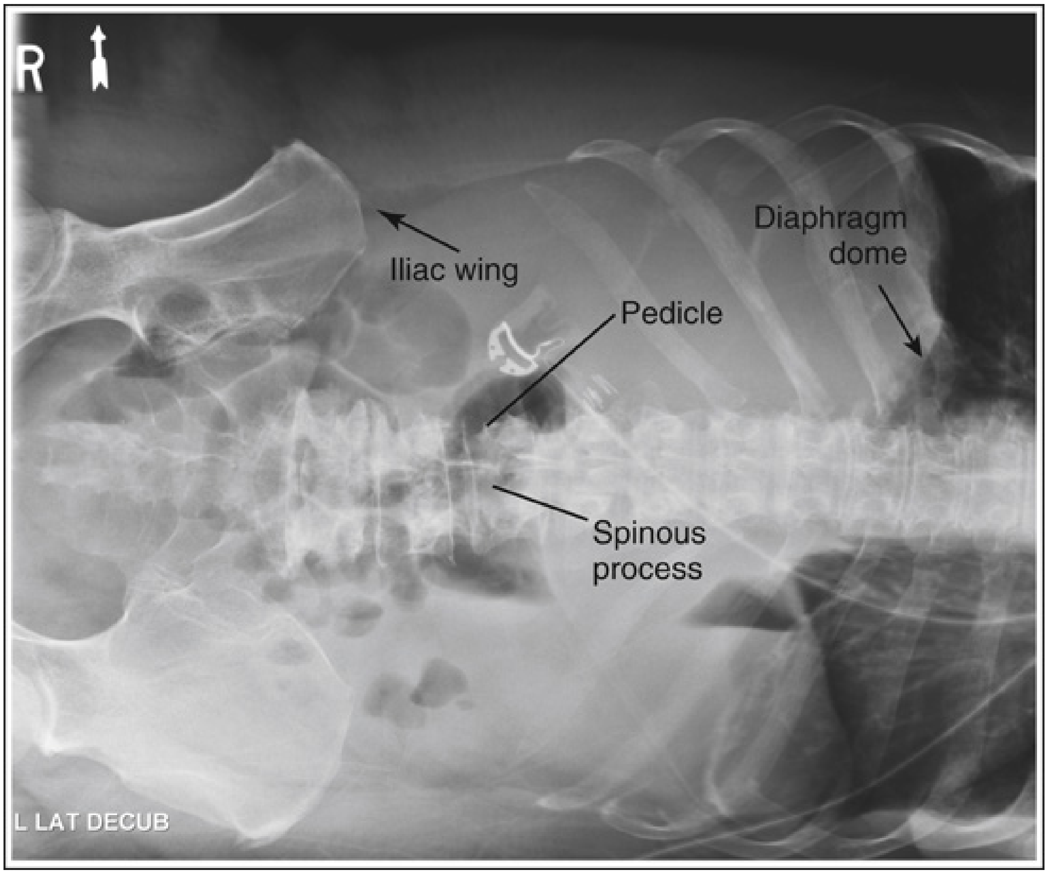


FIGURE 3.133 AP (left lateral decubitus) abdomen with accurate positioning.

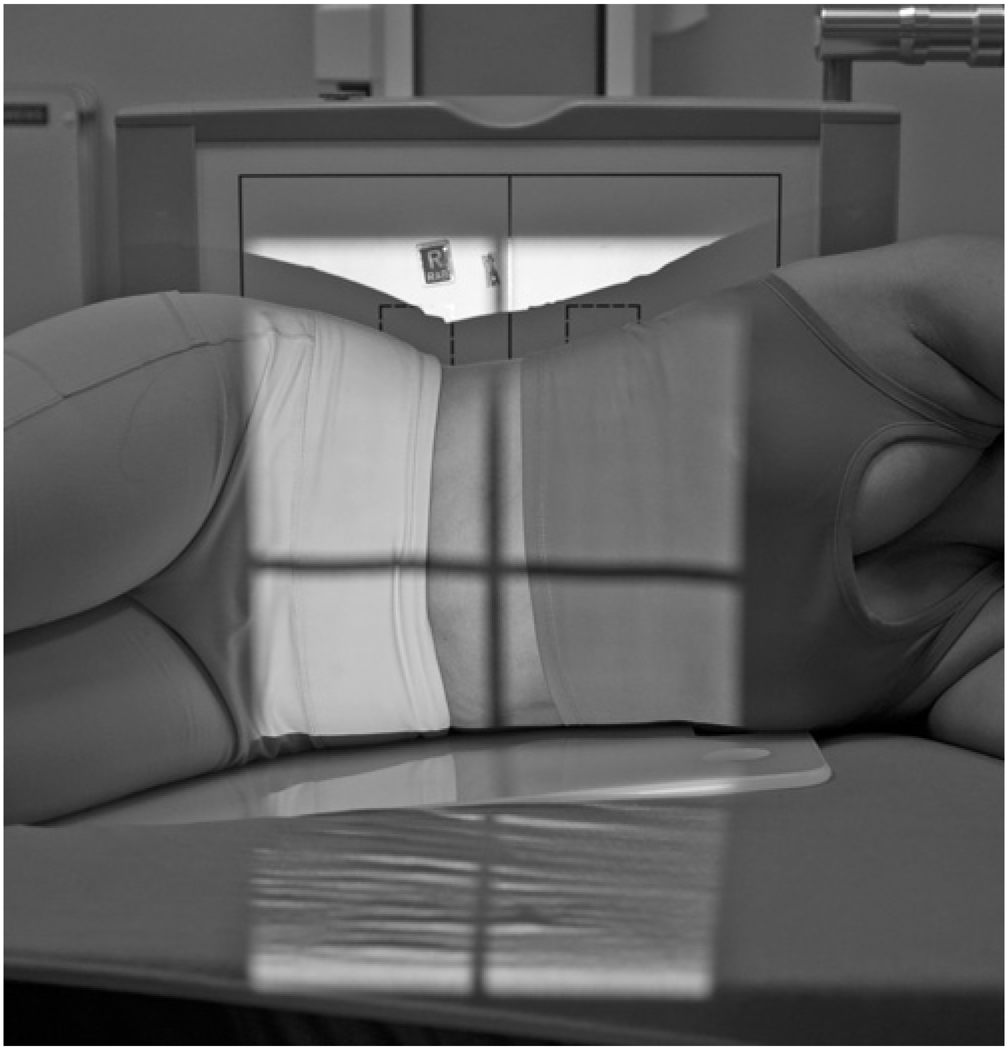


FIGURE 3.134 Proper patient positioning for AP (left lateral decubitus) abdomen projection.

Hypersthenic and Obese Patient IR Placement

When using the computed radiography system, position two IRs crosswise with respect to the patient to include all the necessary anatomic structures in the hypersthenic patient. Take the first projection with the side of the IR placed at a level 2.5 inches (6.25 cm) superior to the xiphoid. Position the top of the second IR such that it includes approximately 2 to 3 inches (5 to 7.5 cm) of the same transverse section of the peritoneal cavity imaged on

the first projection to ensure that no middle peritoneal information has been excluded. For the obese patient, the IR and the CR centering may need to be offset from the midsagittal plane toward the side up and away from the imaging table or cart to include the required hemidiaphragm and iliac wing.

Demonstrating Intraperitoneal Air

The AP (decubitus) projection is primarily used to confirm the presence of intraperitoneal air. In the AP decubitus position, intraperitoneal air will rise to the highest level, which in most patients means it moves to the right upper quadrant just below the elevated hemidiaphragm, between the liver and abdominal wall. The left over the right lateral decubitus position is chosen to place the gastric bubble away from the elevated hemidiaphragm, preventing it from being mistaken for intraperitoneal air. For intraperitoneal air to be demonstrated best, the patient should be left in the lateral decubitus position for 5 to 20 minutes before the projection is taken, allowing enough time for the air to move away from the soft-tissue abdominal structures and rise (**Fig. 3.135**). To eliminate long waiting periods for patients who are scheduled to have a decubitus abdomen, have them transported to the imaging department in the left lateral recumbent position.

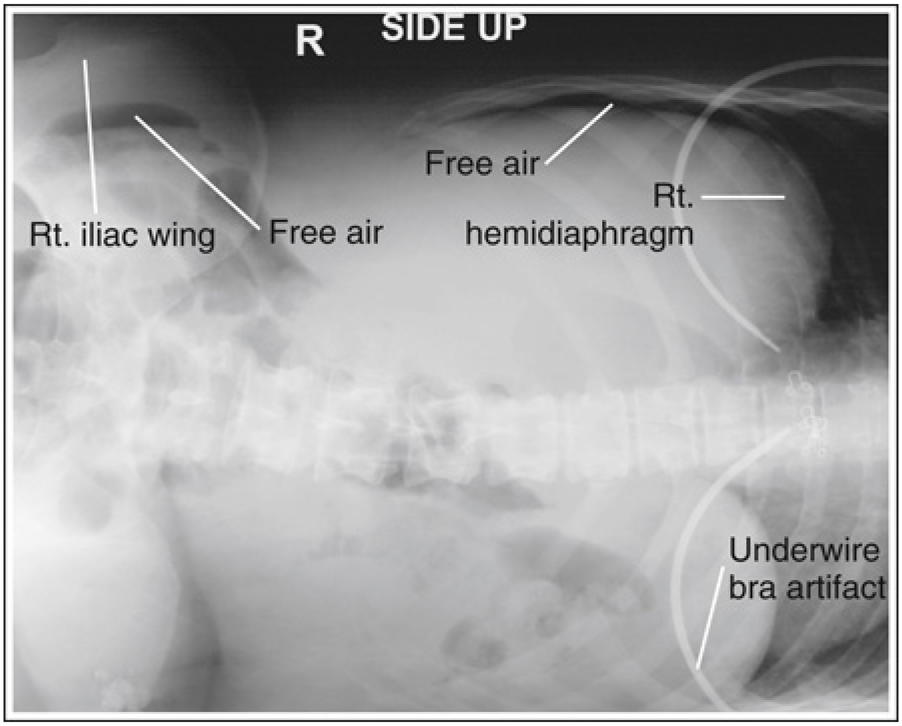


FIGURE 3.135 AP (left lateral decubitus) abdomen demonstrating free intraperitoneal air under right hemidiaphragm and right iliac wing.

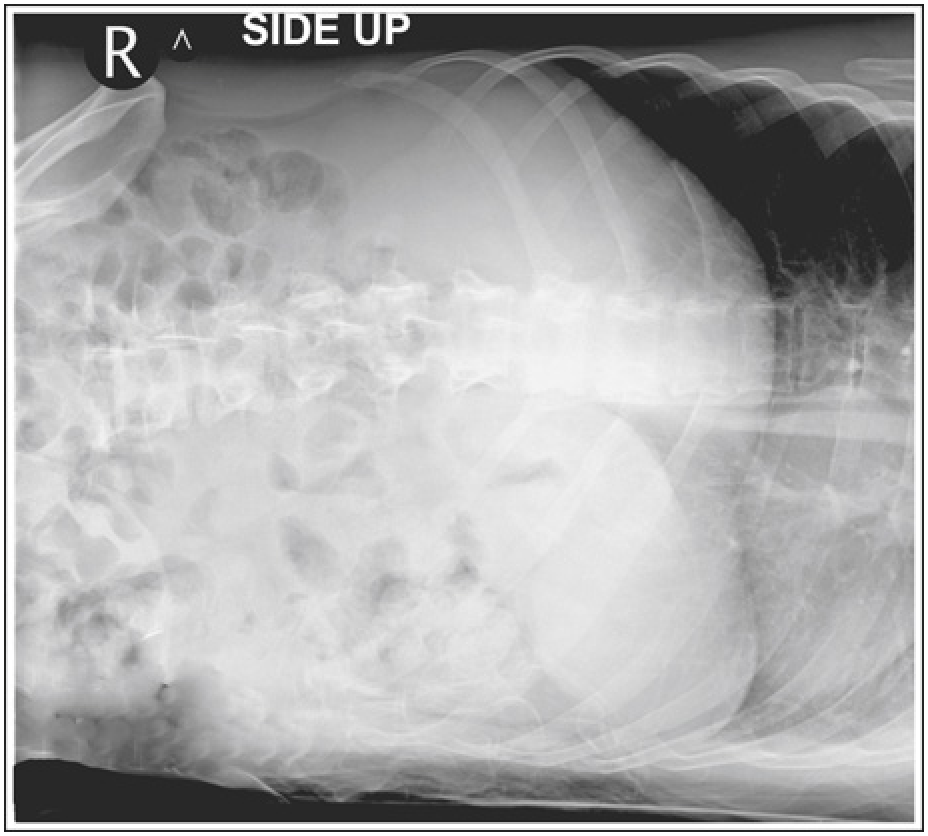


FIGURE 3.136 AP (left lateral decubitus) abdomen taken with left side of abdomen rotated closer to IR than right side.

Patients With Wide Hips

In women with wide hips, the right hemidiaphragm and iliac wing should be included on the projection, as the highest level within the peritoneal cavity in such a patient is just over the iliac bone (see **Fig. 3.136**).

Abdominal Rotation

Rotation is effectively detected on an AP abdominal (decubitus) projection by comparing the distance from the pedicles to the spinous processes on each side and the symmetry of the iliac wings. If the distance from the pedicles to the spinous processes is greater on one side of the vertebrae than

on the other side, the side with the smaller distance between the pedicles and spinous processes was the side of the patient positioned farther from the IR. If the iliac wings are not symmetrical, the narrower wing is on the side of the patient positioned farther from the IR (**Fig. 3.136**).

AP (Left Lateral Decubitus) Abdomen Analysis Practice

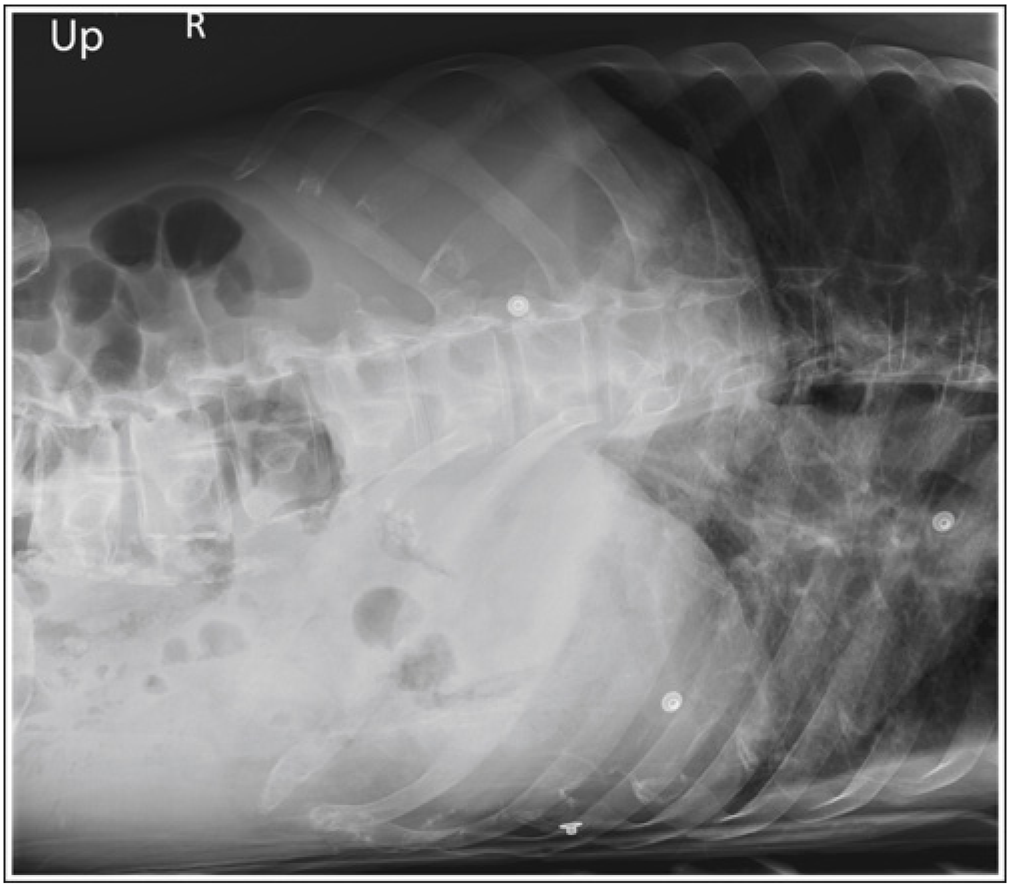


IMAGE 3.32

Analysis

The distances from the left pedicles to the spinous processes are greater than the distances from the right pedicles to the spinous process, and the right iliac wing is narrower than the left iliac wing. The right side of the

patient was positioned further from the IR than the left side. There are snap artifacts in areas of interest.

Correction

Rotate the right side of the patient toward the IR until the midcoronal plane is aligned parallel with the IR. Place a pillow between the knees to help the patient hold accurate positioning. Remove the snap artifacts.

Pediatric Abdomen

In infants and young children, it is difficult to differentiate between the small and large bowels. The gas loops tend to look the same. The abdominal organs (such as kidneys) are also not well defined because little intrinsic fat is present to outline them.

Neonate and Infant Abdomen: AP Projection (Supine)

See **Table 3.19** and Figs. **3.137** and **3.138**.

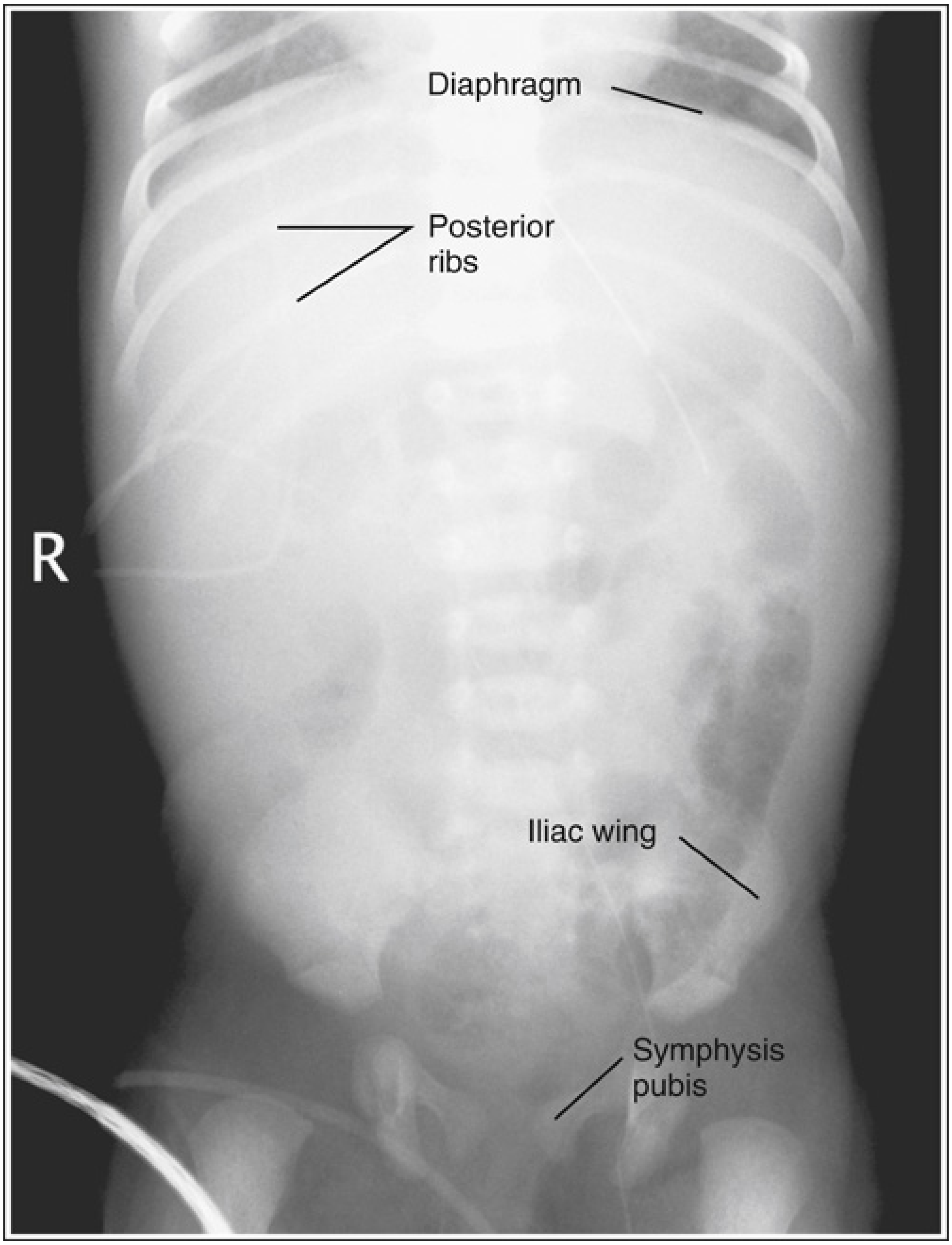


FIGURE 3.137 Neonatal AP abdomen projection with accurate positioning.

TABLE 3.19

CR, Central ray; *IR*, image receptor.

Lumbar Vertebrae Alignment With IR

Aligning the long axis of the lumbar vertebral column with the long axis of the collimated field allows for tighter transverse collimation (**Fig. 3.139**).

FIGURE 3.138 Proper patient positioning for AP neonate and infant abdomen projection.

Abdominal Rotation

The upper and lower lumbar vertebrae can demonstrate rotation independently or simultaneously, depending on which section of the body is rotated. Rotation is effectively detected on an AP abdomen projection by comparing the symmetry of the inferior posterior ribs and the iliac wings (**Fig. 3.140**). The ribs that demonstrate the longer length and the iliac wing demonstrating the greater width are on the side toward which the patient is rotated.

Respiration

On full expiration the diaphragm dome is demonstrated above the eighth posterior rib. If the AP projection is taken on inspiration, the inferior placement of the diaphragm puts pressure on the abdominal organs, resulting in less space in the peritoneal cavity and greater abdominal density (see **Fig. 3.140**).

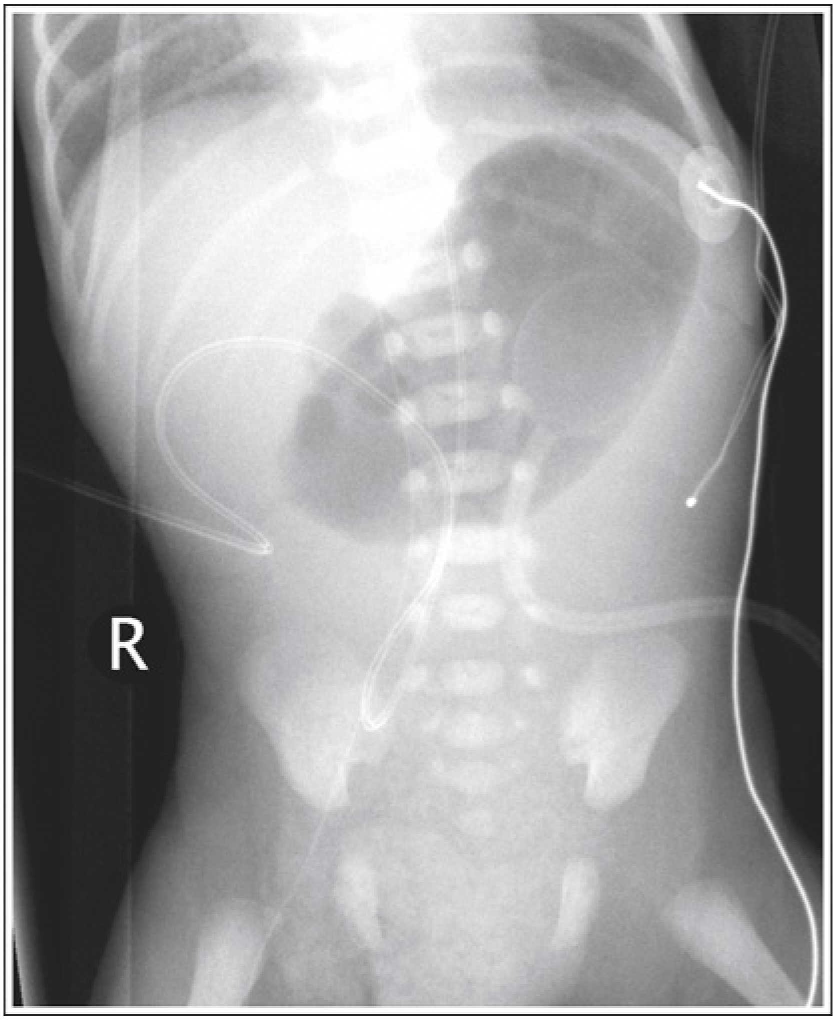


FIGURE 3.139 Neonate AP abdomen taken without alignment of the long axis of the vertebral column and the collimator light field.

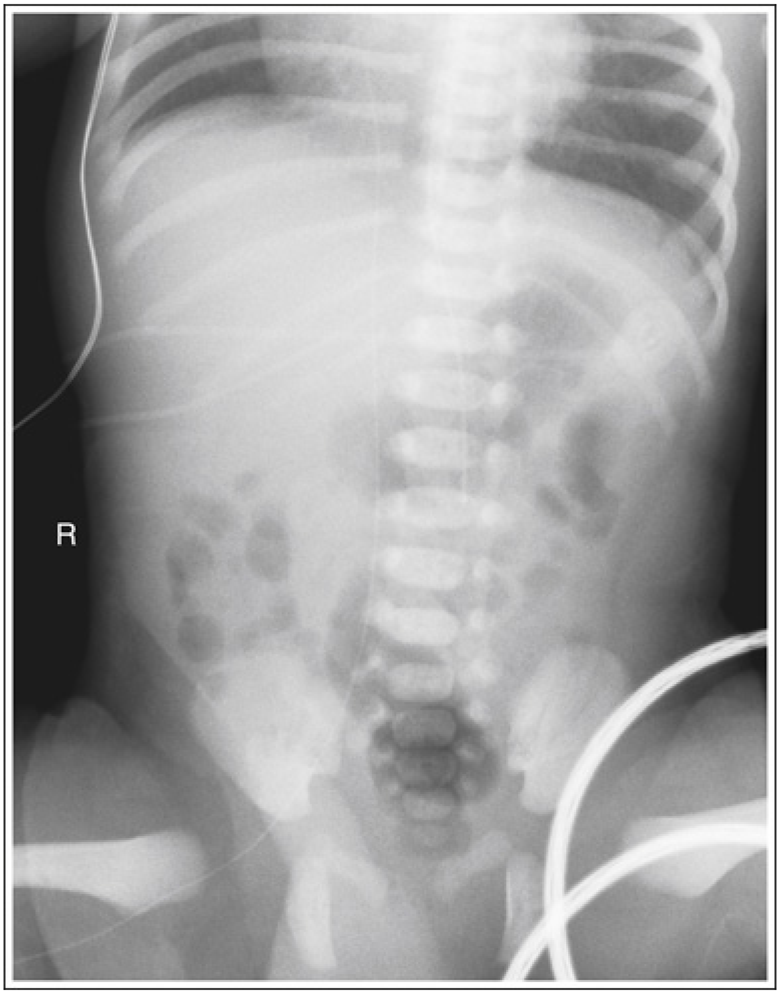


FIGURE 3.140 Neonate AP abdomen taken with right side of abdomen rotated closer to IR than left side (RPO position) and with full lung aeration.

Ventilated Patient

If a high-frequency ventilator is being used, the exposure may be made at any time, but because this ventilator maintains the lung expansion at a steady mean pressure, the projection will not be able to be taken on expiration. This will result in an acceptable projection demonstrating the diaphragm domes below the eighth posterior rib.

Neonate and Infant AP Abdominal Analysis Practice

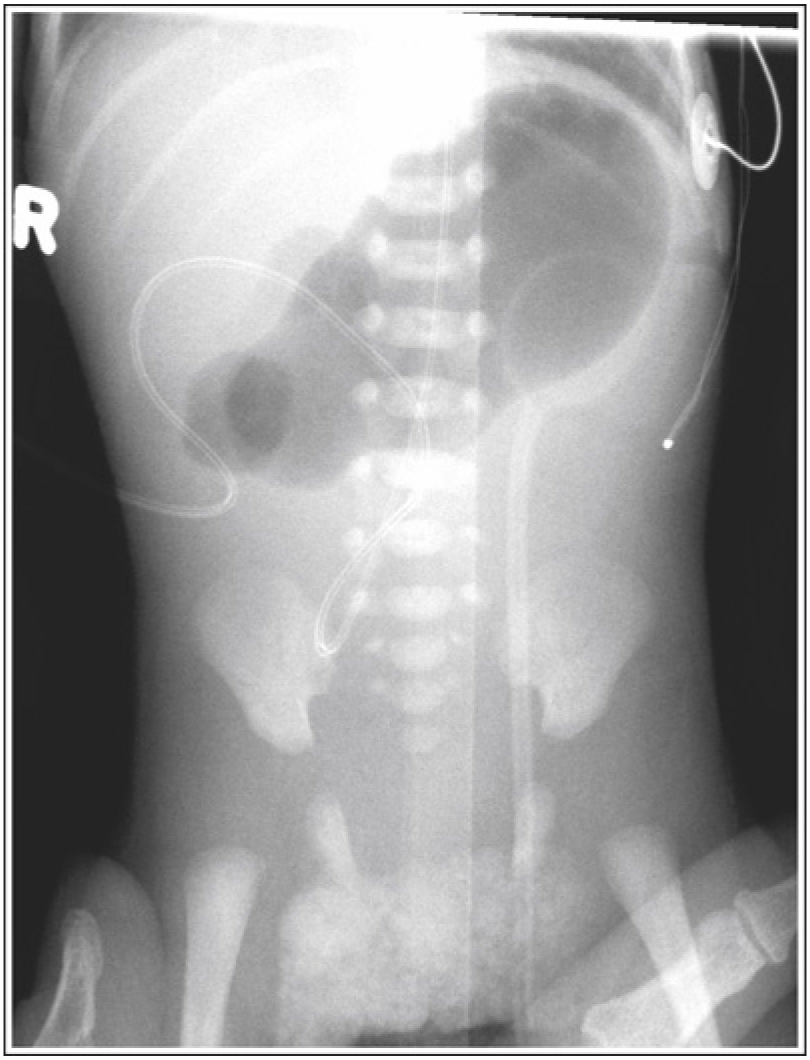


IMAGE 3.33

NEONATE.

Analysis

The diaphragm is not included on the projection, and anatomic artifacts (positioning attendant's fingers, diaper, and lines down the middle of vertebral column) are demonstrated in the exposure field.

Correction

Move the CR and IR 1 inch (2.5 cm) superiorly, and move the attendant's hands and diaper inferiorly outside of the collimated field and discover what is causing the lines that are superimposing the vertebral column to see if it can be removed.

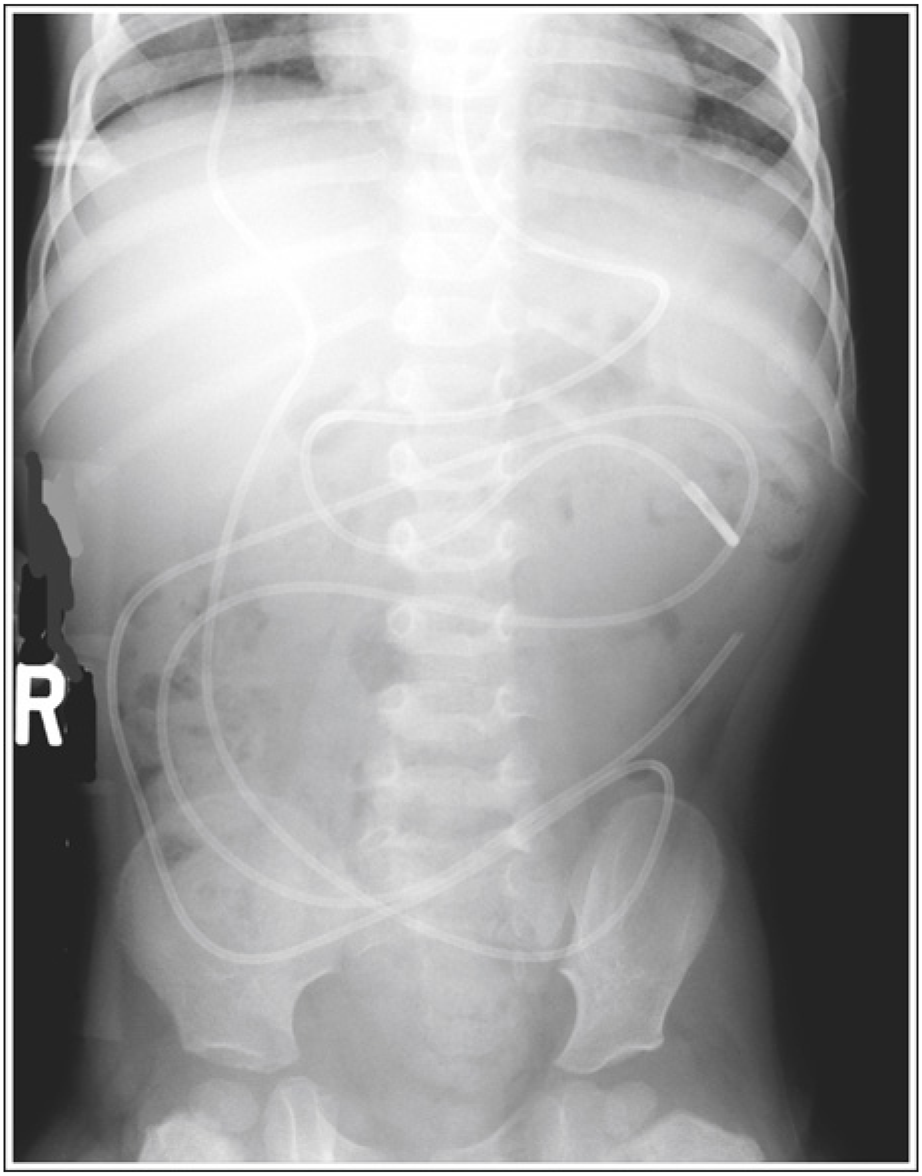


IMAGE 3.34

NEONATE.

Analysis

The right posterior ribs are longer than the left, and the right iliac wing is wider than the left, indicating that the patient was rotated toward the right

side.

Correction

Rotate the left side of the patient toward the IR until the midcoronal plane is aligned parallel with the IR.

Child Abdomen: AP Projection (Supine and Upright)

See **Table 3.20** and Figs. **3.141** to **3.144**.

The analysis of child AP abdomen projections is the same as that of infant or adult AP abdomen projections (see earlier). The size of the child determines which guidelines best meet the situation. For a discussion on topics needed to analyze the following image, refer to the adult or infant abdominal discussion earlier in this chapter.

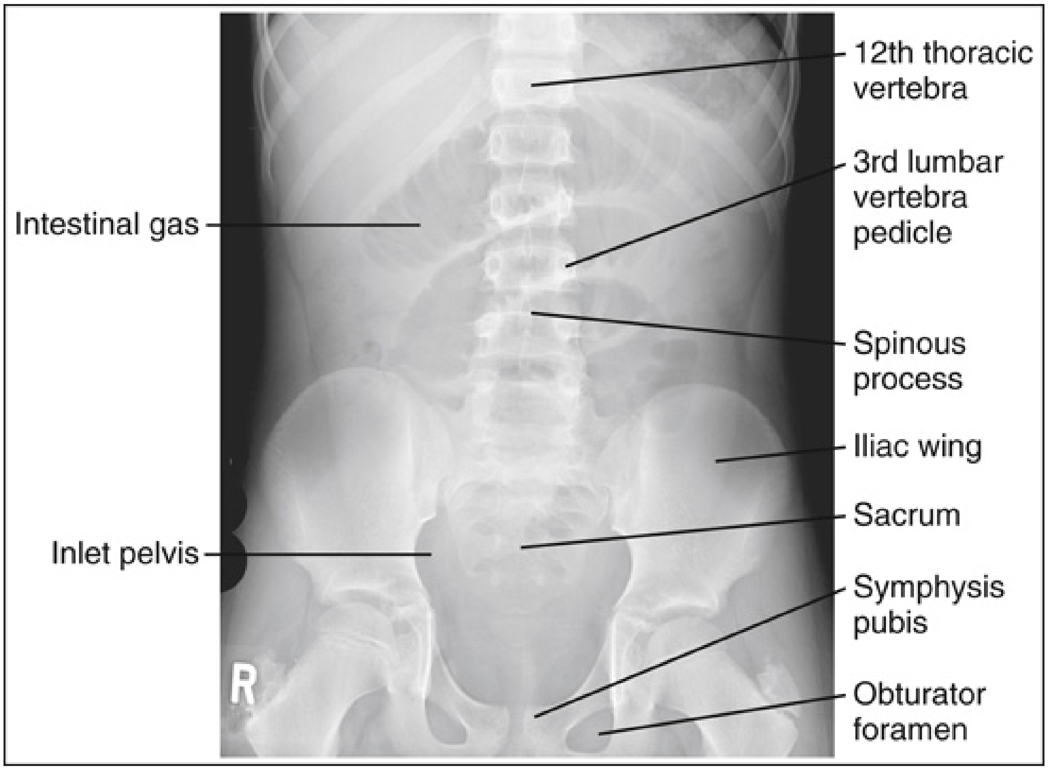


FIGURE 3.141 Child supine AP abdomen projection with accurate positioning.

TABLE 3.20

CR, Central ray; *IR*, image receptor.

![image]

FIGURE 3.142 Child upright AP abdomen projection with accurate positioning.

image

FIGURE 3.143 Proper positioning for a child supine AP abdomen projection.

image

FIGURE 3.144 Proper positioning for a child upright AP abdomen projection.

Child AP Abdominal Analysis Practice

image

IMAGE 3.35

CHILD—UPRIGHT.

Analysis

The diaphragm is not included on this projection. The CR and IR are positioned too inferiorly.

Correction

Move the CR and IR 2 inches (5 cm) superiorly.

Neonate and Infant Abdomen: AP Projection (Left Lateral Decubitus Position)

See **Table 3.21** and Figs. **3.145** and **3.146**.

Demonstrating Free Intraperitoneal Air

To demonstrate free intraperitoneal air best, the patient should be left in this position for a few minutes to allow enough time for the air to move away from the soft tissue abdominal structures and rise to the level of the right diaphragm. With the AP (decubitus) projection, intraperitoneal air will rise to the highest level of the right hemidiaphragm, so it must be included (**Fig. 3.147**).

Abdominal Rotation

Rotation is effectively detected on an AP (decubitus) abdominal projection by comparing the symmetry of the posterior ribs and the iliac wings (**Fig. 3.148**). The ribs that demonstrate the longer length and the ilium demonstrating the greater width are present on the side toward which the patient is rotated.

TABLE 3.21

CR, Central ray; *IR*, image receptor.

image

FIGURE 3.145 Neonatal AP (left lateral decubitus) abdomen projection with accurate positioning.

image

FIGURE 3.146 Proper patient positioning for AP (left lateral decubitus) neonate and infant abdomen projection.

image

FIGURE 3.147 AP (left lateral decubitus) neonate abdomen demonstrating intraperitoneal air.

image

FIGURE 3.148 AP (left lateral decubitus) neonate abdomen taken with left side of abdomen rotated closer to IR than right side.

Neonate and Infant AP (Left Lateral Decubitus) Abdominal Analysis Practice

image

IMAGE 3.36

NEONATE.

Analysis

The left-side posterior ribs are longer than the right side, and the right iliac wing is wider than the left, indicating that the patient was rotated toward the left side.

Correction

Rotate the right side of patient toward the IR until the midcoronal plane is aligned parallel with the IR.

Child Abdomen: AP Projection (Left Lateral Decubitus Position)

See **Table 3.22** and Figs. **3.149** and **3.150**.

The analysis of the child AP (left lateral decubitus) abdominal projection is the same as that of the infant or adult AP (left lateral decubitus) abdomen (see earlier). The size of the child determines which guidelines best fit the situation. For discussion on topics needed to analyze the following image, refer to the earlier discussion of adult or infant AP (decubitus) abdomen projections.

TABLE 3.22

CR, Central ray; *IR*, image receptor.

image

FIGURE 3.149 Child AP (left lateral decubitus) abdomen projection with accurate positioning.

image

FIGURE 3.150 Proper positioning for a child AP (left lateral decubitus) abdomen projection.

Child AP (Left Lateral Decubitus) Abdomen Analysis Practice

image

IMAGE 3.37

CHILD.

Analysis

The right-side posterior ribs are longer than the left side, and the right iliac wing is wider than the left, indicating that the patient was rotated toward the right side.

Correction

Rotate the right side of the patient away from the IR until the midcoronal plane is aligned parallel with the IR.

Lung Development

The lungs of the neonate continue to grow for at least 8 years after birth. The growth results mainly from an increase in the number of respiratory bronchioles and alveoli. Only from one-eighth to one-sixth of the number of

alveoli in adults are present in newborn infants, causing the lungs to be denser. Therefore, on neonate/infant chest projections, the lungs demonstrate less contrast within them and between them and the surrounding soft tissue than on child/adult chest projections.

Chest Shape and Size

As the lungs grow, the shape of the thoracic cavity changes from the neonate/infant's short, wide shape to the older child/adult's longer, narrower shape. To accommodate these changes, the CR will require a more inferior centering, and the degree of collimation will need to be reduced as the infant grows to adulthood. For computed radiography systems, this also requires larger IR cassettes to be chosen as the infant grows. For best spatial resolution, choose the smallest possible IR cassette that will accommodate the required structures.

Technical Data

See **Table 3.15** and **Box 3.2**.

Subject Contrast and Brightness

The subject contrast and image brightness are adequate on adult abdominal projections when the collections of fat that outline the psoas major muscles and kidney, as well as the bony structures of the inferior ribs and transverse processes of the lumbar vertebrae, are visualized. Because soft tissue abdominal structures are similar in atomic number and tissue density, whether two soft tissue structures that border each other are visible or not depends on their arrangement with respect to the gas and fat collections that lie next to them, around them, or within them. These same gas and fat collections are used to identify diseases and masses within the abdomen. The presence or absence of gas, as well as its amount and location within

the intestinal system, may indicate a functional, metabolic, or mechanical disease, whereas routinely seen collections of fat may be displaced or obscured with organ enlargement or mass invasion.

Locating the Psoas Major Muscles and Kidneys

The psoas major muscles are located laterally to the lumbar vertebrae. They originate at the first lumbar vertebra on each side and extend to the corresponding lesser trochanter. On an AP abdominal projection, the psoas major muscles are visible as long, triangular, soft tissue shadows on each side of the vertebral bodies. The kidneys are found in the posterior abdomen and are identified on abdominal projections as bean-shaped densities located on each side of the vertebral column 3 inches (7.5 cm) from the midline. The upper poles of the kidney lie on the same transverse level as the spinous process of the eleventh thoracic vertebra, and the lower poles lie on the same transverse level as the spinous process of the third lumbar vertebra. The right kidney is usually demonstrated approximately 1 inch (2.5 cm) inferior to the left kidney because of its location beneath the liver. Occasionally a kidney may be displaced inferiorly (nephroptosis) to this location, because it is not held in place by adjacent organs or its fat covering; this condition is most often seen in thin patients.

TABLE 3.15

[a] Use grid if part thickness measures 4 inches (10 cm) or more.

FIGURE 3.112 Supine AP abdomen demonstrating excessive bowel gas.

Box 3.2 Abdomen Guidelines

- The facility's identification requirements are visible.
- A right and left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Cortical outlines of the posterior ribs, lumbar vertebrae, and pelvis and the gases within the stomach and intestine lines are sharply defined.
- Adult: Contrast resolution is adequate to demonstrate the collections of fat that outline the psoas major muscles and kidneys, and the bony structures of the inferior ribs and transverse processes of the lumbar vertebrae.
- Children: Contrast resolution is adequate to demonstrate the diaphragm, bowel gas pattern, and faint outline of bony structures.
- No quantum mottle or saturation is present.
- Scattered radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

VOI, Values of interest.

Adjusting Technical Data for Patient Conditions

Bowel Gas

The routinely set technical factors obtained from the AP body measurement of patients with suspected large amounts of bowel gas may cause IR overexposure and saturation in areas of the abdomen that are overlaid with gas (**Fig. 3.112**). (The patient measures the same whether gas or dense soft tissue causes the thickness.) This decreased brightness results from the low tissue density characteristic of gas. As the radiation passes through the body, fewer photons are absorbed where gas is located than where dense soft tissue is present. To compensate for this situation, decrease the exposure (mAs) 30% to 50% or the kV 5% to 8% from the routinely used manual technique before the projection is taken.

Ascites, Obesity, Bowel Obstruction, or Soft Tissue Masses

An underexposed projection may result when patients have ascites, obesity, bowel obstructions, or soft tissue masses. This is because sections of the abdomen that normally contain gas or fat do not, resulting in an increase in the tissue density of the soft tissue. To compensate for this situation, increase the exposure (mAs) 30% to 50% or the kV 5% to 8% from the routinely used technique before the projection is taken.

Upright: Pendulous Breasts

Large pendulous breasts may obscure the upper abdominal area on the upright AP abdomen projection, as they add a thicker, dense region to this area. To reduce this tissue density and provide more uniform brightness across the abdomen, have the patient elevate and shift the breasts laterally for the projection (**Fig. 3.113**).

FIGURE 3.113 Upright AP abdomens comparing brightness change when pendulous breasts are moved laterally.

Abdominal Lines, Devices, Tubes, and Catheters

Familiarizing yourself with the accurate placement of the devices, lines, and catheters that are seen on abdominal projections will provide the information needed to identify when proper technique was used to visualize them and when poor placement is suspected.

Nasogastric Tubes

The nasogastric (NG) tube passes through the nose and extends to the stomach. The NG tube is used for feeding, when the patient is unable to swallow normally because of trauma or disease, for the removal of gas and secretions by suction (decompression), and for radiographic examinations of the stomach. Projections taken that demonstrate the NG tube should demonstrate adequate subject contrast to visualize the upper left abdominal region (**Fig. 3.114**).

FIGURE 3.114 Supine AP abdomen with accurate nasogastric tube placement.

Spinal Stimulator Implant

The spinal stimulator implant is used to treat chronic pain. The stimulator is implanted under the skin in the abdomen, and the leads are inserted under

the skin to where they are inserted into the spinal canal. Projections taken that demonstrate the spinal stimulator should demonstrate adequate subject contrast to visualize the abdominal and spinal structures (**Fig. 3.115**).

Upright: Free Intraperitoneal Air

The upright AP abdomen is most often used to evaluate the peritoneal cavity for intraperitoneal air. For intraperitoneal air to be demonstrated best, the patient should be positioned upright for 5 to 20 minutes before the projection is taken. This allows enough time for the air to move away from the soft tissue abdominal structures and rise to the level of the diaphragm (**Fig. 3.116**). If a patient has come to the imaging department for a supine and upright abdominal series, begin with the upright projection if the patient is ambulatory (able to walk) or transported by wheelchair. An ambulatory or wheelchair-using patient has been upright long enough for the air to rise, so it is not necessary to wait to take the projection.

FIGURE 3.115 AP abdomen and lateral vertebrae demonstrating spinal stimulator implant.

FIGURE 3.116 Upright AP abdomen demonstrating free intraperitoneal air.

Variations in Positioning Procedure Due to Body Habitus

Because the abdominal cavity varies in size and length, owing to differences in body habitus, and because the abdomen carries much of the fat tissue on the obese patient, there is not a standard protocol that can be followed for all patients for the number of IRs that are needed, the IR size and direction to use, or where the CR is centered. These are chosen so that when all the projections obtained for the exam are combined, they together include all of the required image analysis guidelines. Failing to choose correctly results in clipped structures and an incomplete picture of the peritoneal cavity (**Fig. 3.117**). The guidelines in Tables **3.16** and **3.17** are for the routine sthenic, hyposthenic, and asthenic, nonobese patient, with descriptions for other body habitus to follow. The sthenic and hyposthenic patients make up about 85% of the population.

Chapter 4: Image Analysis of the Upper Extremity

OBJECTIVES

AFTER COMPLETION OF THIS CHAPTER, YOU SHOULD BE ABLE TO DO THE FOLLOWING:

- IDENTIFY THE REQUIRED ANATOMY ON UPPER EXTREMITY PROJECTIONS.
- DESCRIBE HOW TO PROPERLY POSITION THE PATIENT, IMAGE RECEPTOR (IR), AND CENTRAL RAY (CR) ON UPPER EXTREMITY PROJECTIONS.
- LIST THE IMAGE ANALYSIS GUIDELINES FOR UPPER EXTREMITY PROJECTIONS WITH ACCURATE POSITIONING.

- STATE HOW TO REPOSITION THE PATIENT PROPERLY WHEN UPPER EXTREMITY PROJECTIONS WITH POOR POSITIONING ARE PRODUCED.
- DISCUSS HOW TO DETERMINE THE AMOUNT OF PATIENT OR CR ADJUSTMENT REQUIRED TO IMPROVE UPPER EXTREMITY PROJECTIONS WITH POOR POSITIONING.
- STATE THE KILOVOLTAGE (KV) THAT IS ROUTINELY USED FOR UPPER EXTREMITY PROJECTIONS, AND DESCRIBE WHICH ANATOMIC STRUCTURES WILL BE VISIBLE WHEN THE CORRECT TECHNICAL FACTORS ARE USED.
- LIST THE SOFT TISSUE STRUCTURES THAT ARE OF INTEREST ON UPPER EXTREMITY PROJECTIONS. STATE WHERE THEY ARE LOCATED AND DESCRIBE WHY THEIR VISUALIZATION IS IMPORTANT.
- EXPLAIN HOW WRIST AND ELBOW ROTATIONS AFFECT THE POSITION OF THE RADIAL AND ULNAR STYLOIDS.
- DISCUSS HOW A PATIENT WITH LARGE, MUSCULAR, OR THICK PROXIMAL FOREARMS SHOULD BE POSITIONED FOR GOOD POSTEROANTERIOR (PA) AND LATERAL WRIST PROJECTIONS TO BE OBTAINED.
- STATE THE CARPAL BONE CHANGES THAT OCCUR WHEN THE WRIST IS EXTENDED, DEVIATED, OR ULNAR- AND RADIAL-DEVIATED IN THE PA AND LATERAL PROJECTIONS.

- DESCRIBE HOW THE POSITIONING PROCEDURE IS ADJUSTED IF WRIST PROJECTIONS ARE ORDERED WITH A REQUEST THAT MORE THAN ONE-FOURTH OF THE DISTAL FOREARM BE INCLUDED.
- EXPLAIN HOW AND WHY THE CR IS ADJUSTED FOR THE PA ULNAR-DEVIATED SCAPHOID PROJECTION IF A PROXIMAL OR DISTAL SCAPHOID FRACTURE IS IN QUESTION AND IF A PATIENT CANNOT ADEQUATELY ULNAR-FLEX.
- LIST PALPABLE STRUCTURES USED TO IDENTIFY THE LOCATION OF THE ELBOW AND GLENOHUMERAL JOINTS.
- EXPLAIN HOW THE PATIENT IS POSITIONED IF ONLY ONE JOINT CAN BE PLACED IN ITS TRUE POSITION FOR AP AND LATERAL FOREARM AND HUMERAL PROJECTIONS.
- DISCUSS HOW HAND- AND WRIST-POSITIONING WILL AFFECT VISUALIZATION OF THE RADIAL TUBEROSITY ON LATERAL ELBOW PROJECTIONS.
- STATE WHY THE HUMERUS IS NEVER ROTATED IF A HUMERAL FRACTURE IS SUSPECTED.

KEY TERMS **CARPAL CANAL CONCAVE CONVEX DISTAL EXTENSION EXTERNAL ROTATION FAT PAD FLEXION INTERNAL ROTATION INTERPHALANGEAL (IP) JOINT EFFUSION LATERAL MEDIAL METACARPOPHALANGEAL (MCP) PALMAR PRONATE PRONATOR FAT STRIPE PROXIMAL PROXIMAL IP (PIP) RADIAL DEVIATION SCAPHOID FAT STRIPE ULNAR DEVIATION**

Image Analysis Guidelines

Technical Data

See **Table 4.1** and **Box 4.1**.

Finger: PA Projection

See **Table 4.2** and Figs. **4.1** and **4.2**.

Finger Rotation

Finger rotation is controlled by how tightly the palm is placed flat against the image receptor (IR). When the hand is allowed to relax and the palm is lifted slightly away from the IR, rotation occurs. Because the thumb prevents the hand from internally rotating, external rotation is the most common rotational error. Study the finger projections in **Fig. 4.3**. In the posteroanterior (PA) projection, concavity of the phalanges is equal on both sides, and in the lateral projection the anterior surface is concave and the posterior surface is slightly convex. As the finger is rotated medially for a PA oblique projection, the amount of concavity increases on the side that the anterior surface is rotated toward and decreases on the side that the posterior surface is rotated toward. The same observations can be made about the soft tissue that surrounds the phalanges. More soft tissue thickness is present on the anterior hand surface than on the posterior surface, so the side demonstrating the greatest soft tissue width on a rotated PA or a PA oblique projection is the side that the anterior surface was rotated toward. This information can be used to determine whether the finger was externally or internally rotated when a poorly positioned PA finger has been obtained.

TABLE 4.1

[a] Use grid if part thickness measures 4 inches (10 cm) or more and adjust mAs per grid ratio requirement.

Box 4.1 Upper Extremity Guidelines

VOI, Values of interest.

- The facility's identification requirements are visible.
- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomical structures are sharply defined.
- Contrast resolution is adequate to demonstrate the surrounding soft tissue, bony trabecular patterns, and cortical outlines.
- No quantum mottle or saturation is present.
- Scatter radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

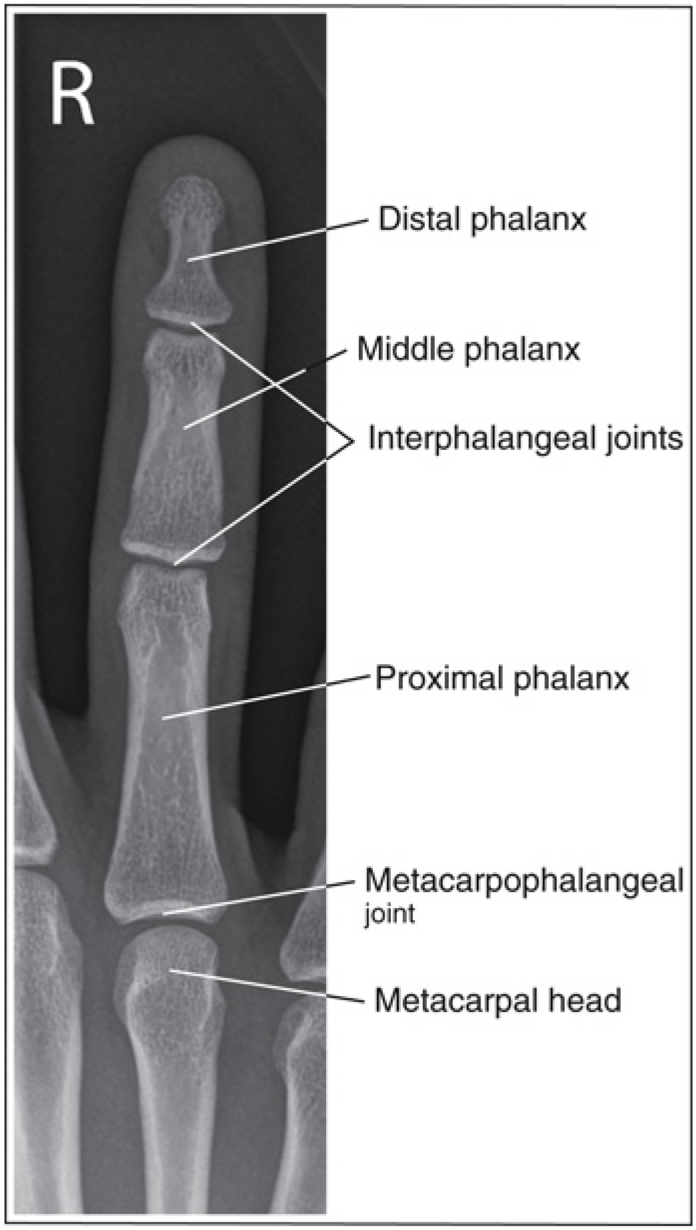


FIGURE 4.1 PA finger projection with accurate positioning.

TABLE 4.2

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MC,* metacarpal; *MCP*, metacarpophalangeal; *PA*, posteroanterior; *PIP*, proximal interphalangeal.

External Finger Rotation

If the anterior surface is rotated toward the longest second metacarpal (MC) or thumb, the finger was externally rotated (**Fig. 4.4**).

Internal Finger Rotation

The thumb prevents this movement.

Open IP and MCP Joint Spaces and Nonforeshortened Phalanges

The IP and MCP joint spaces are open and the phalanges are not foreshortened if the finger is fully extended and the central ray (CR) is perpendicular and centered to the proximal interphalangeal (PIP) joint. This finger positioning and CR placement align the joint spaces parallel with the CR and perpendicular to the IR, as shown in **Fig. 4.5**, resulting in open joint spaces. It also prevents foreshortening of the phalanges, because their long axes are aligned parallel with the IR and perpendicular to the CR. The alignment of the CR and IR with the joint spaces and phalanges changes when the finger is flexed (**Fig. 4.6**).

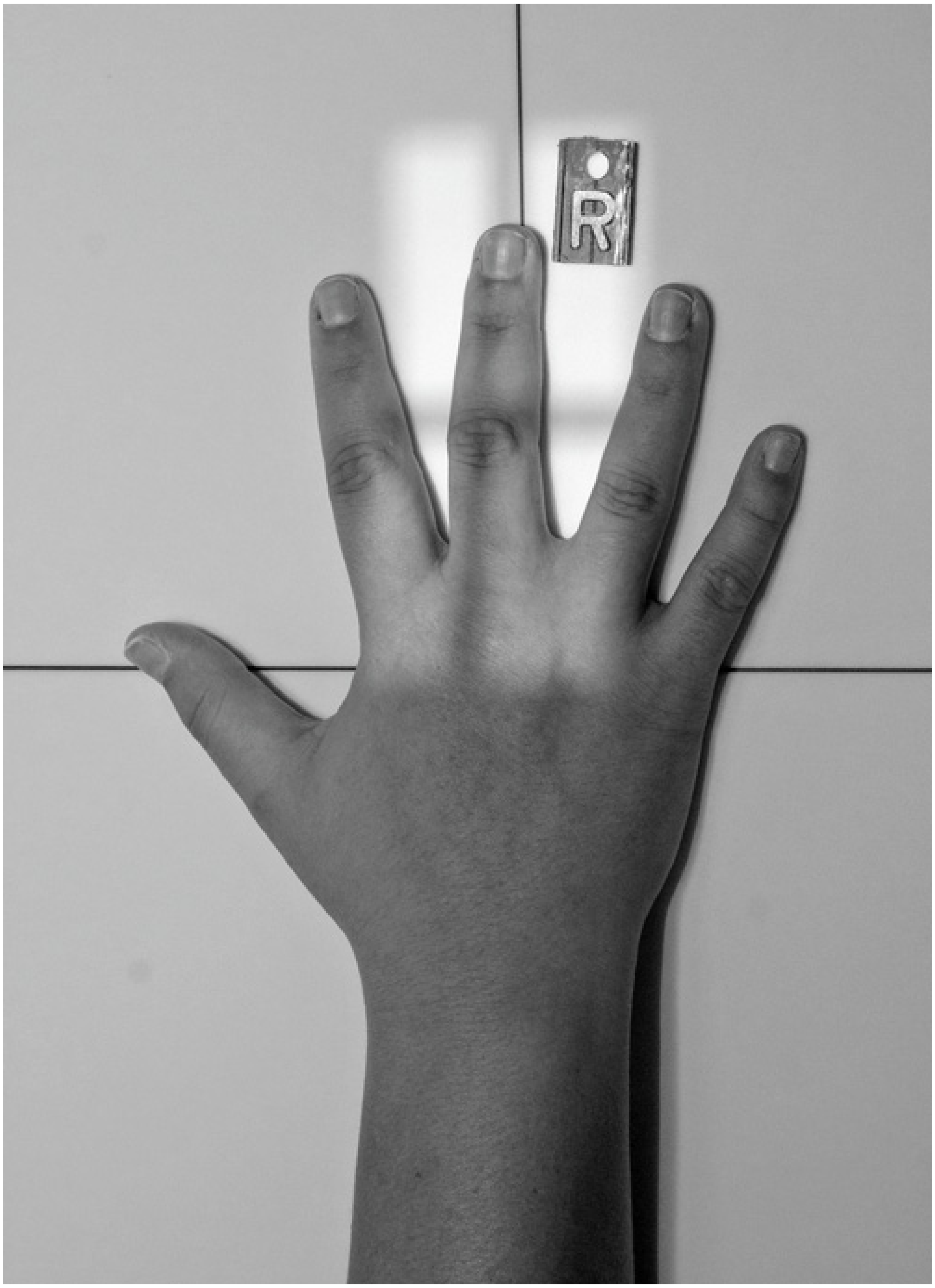


FIGURE 4.2 Proper patient positioning for PA finger projection.

FIGURE 4.3 PA, PA oblique, and lateral finger projections to demonstrate the changes in soft tissue and phalanx concavity between them.

FIGURE 4.4 PA finger projection taken with the finger rotated externally.

Finger Alignment With CR

If the finger is flexed or tilted toward the IR, the CR will be poorly aligned with the joint spaces and phalanges, causing the phalanges to foreshorten and be superimposed on the joint spaces, closing them (**Fig. 4.7**).

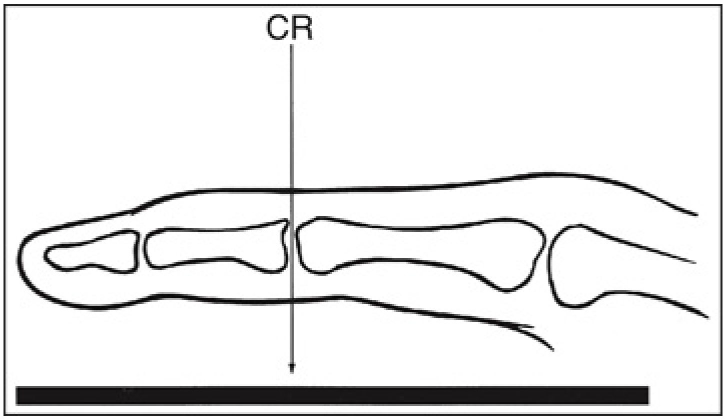


FIGURE 4.5 Accurate alignment of the CR parallel with the joint space to obtain an open joint space.

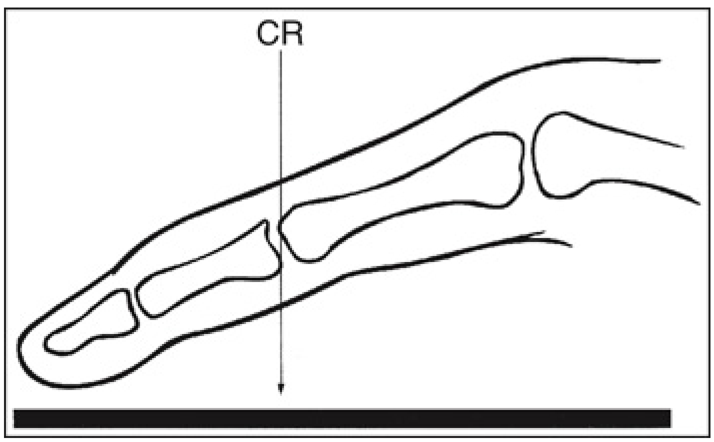


FIGURE 4.6 Poor alignment of joint space and CR.

FIGURE 4.7 PA finger projection taken without the CR aligned parallel with the joint spaces and perpendicular to the phalanges.

Positioning the Nonextendable Finger

If the patient is unable to extend the finger, it may be best to use an anteroposterior (AP) projection to demonstrate open IP and MCP joint spaces and to visualize the phalanges of greatest interest without

foreshortening. In this case, investigate the reason the examination is being performed to determine the phalanx and joint space of interest. Then supinate the hand into an AP projection, elevating the proximal MCs until the phalanges of interest are parallel with the IR and the joint space of interest is perpendicular to the IR (**Fig. 4.8**). Figs. **4.9** and **4.10** demonstrate how this patient positioning can improve phalanx and joint space visualization. For **Fig. 4.9** the patient was imaged in a PA projection with fingers flexed. For **Fig. 4.10** the same patient was imaged in an AP projection with the proximal MCs elevated to place the affected proximal phalanges parallel with the IR.

FIGURE 4.8 Proper positioning for flexed, unextendable fingers to obtain open joint spaces and nonforeshortened phalanges.

FIGURE 4.9 PA projection with flexed fingers.

FIGURE 4.10 AP projection with flexed fingers.

PA Finger Analysis Practice

IMAGE 4.1

Analysis

The side of the digit facing the thumb demonstrates greater phalangeal midshaft concavity and soft tissue width. The finger was externally rotated for the projection.

Correction

Internally rotate the finger, placing it flat against the IR.

IMAGE 4.2

Analysis

The IP and MP joints are closed, and the phalanges are foreshortened. The finger was flexed.

Correction

Extend the finger, and place the palm flat against the IR. If the patient is unable to extend the finger, position it in an AP projection, aligning the phalanx of interest parallel with the IR or affected joint space perpendicular to the IR.

Finger: PA Oblique Projection

See **Table 4.3** and Figs. **4.11** and **4.12**.

Insufficient Finger Rotation

If the phalangeal midshaft concavity and soft tissue width on both sides of the digit are more nearly equal, the finger was rotated less than the required 45 degrees (**Fig. 4.13**).

Excessive Finger Rotation

If the soft tissue width on one side of the digit is more than twice as much as that on the other side, and when one aspect of the phalangeal midshaft is concave but the other aspect is slightly convex, the finger was rotated more than the required 45 degrees (**Fig. 4.14**).

Adjacent Finger Overlap

Failure to slightly separate the fingers causes overlapping of the adjacent finger onto that of the affected finger (**Fig. 4.15**).

Open IP and MCP Joint Spaces and Nonforeshortened Phalanges

When the hand and fingers are rotated to obtain the PA oblique, all but the fifth finger are positioned away from the IR at varying object–IR distances (OIDs) and will naturally flex toward the IR. Failure to position the finger parallel with the IR will result in closed IP and MCP joint spaces and foreshortened phalanges (**Fig. 4.16**).

TABLE 4.3

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MCP*, metacarpophalangeal; *PA*, posteroanterior; *PIP*, proximal interphalangeal.

FIGURE 4.11 PA oblique finger projection with accurate positioning.

FIGURE 4.12 Proper patient positioning for PA oblique finger projection.

FIGURE 4.13 PA oblique finger projection taken with less than 45 degrees of obliquity.

FIGURE 4.14 PA oblique finger projection taken with more than 45 degrees of obliquity.

FIGURE 4.15 PA oblique finger projection taken with the soft tissue from adjacent fingers superimposed over the affected finger's soft tissue.

FIGURE 4.16 PA oblique finger projection taken without the finger positioned parallel with the IR.

PA Oblique Finger Analysis Practice

IMAGE 4.3

Analysis

The soft tissue width and midshaft concave are nearly equal on both sides of the phalanx. The finger was positioned at less than 45 degrees of

obliquity for the projection. The IP and MP joints are closed. The finger was not aligned parallel with the IR.

Correction

Increase the finger obliquity to 45 degrees. Keep finger parallel with the IR.

Finger: Lateral Projection

See **Table 4.4** and Figs. **4.17** and **4.18**.

Adjacent Finger Overlap

If the hand is not drawn into a tight fist, the unaffected fingers will superimpose the proximal phalanx of the affected finger, preventing adequate visualization (**Fig. 4.19**).

Extending Fractured Finger

An extending device should only be used to extend the finger if the device can be positioned proximal to the injured area. **Fig. 4.20** demonstrates two lateral finger projections with fractures. The first projection was obtained on a patient with a proximal phalange fracture that was stressed because the extending device was placed distal to the fracture. The second projection demonstrates a patient with a distal phalange fracture that was not stressed by the extending device because it was placed proximal to the injured area. If the extending device cannot be placed proximal to the injured area, leave the finger positioned as is. This may result in overlap of other fingers and soft tissue onto the affected area and require the need for additional kV to penetrate through the greater thickness if the injured area is superimposed by the other fingers.

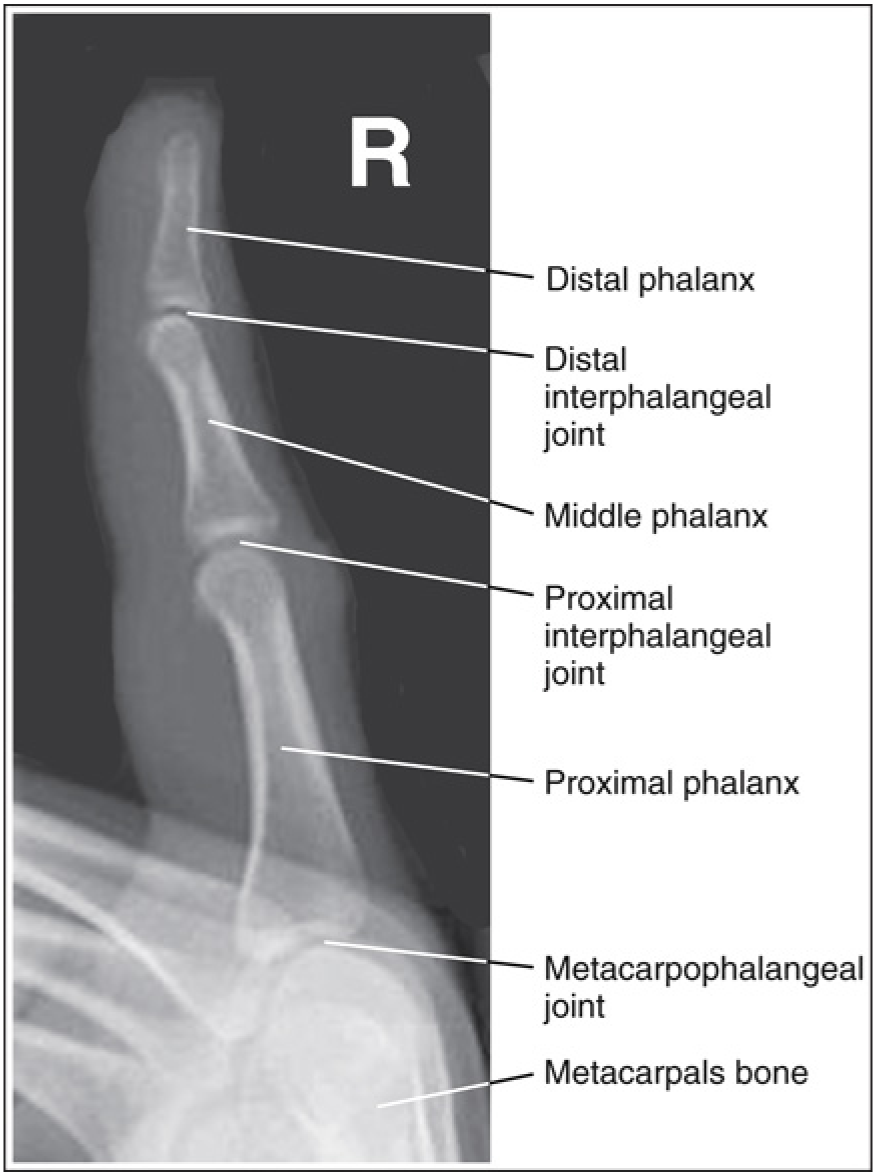


FIGURE 4.17 Lateral finger projection with accurate positioning.

TABLE 4.4

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *PIP*, proximal interphalangeal.

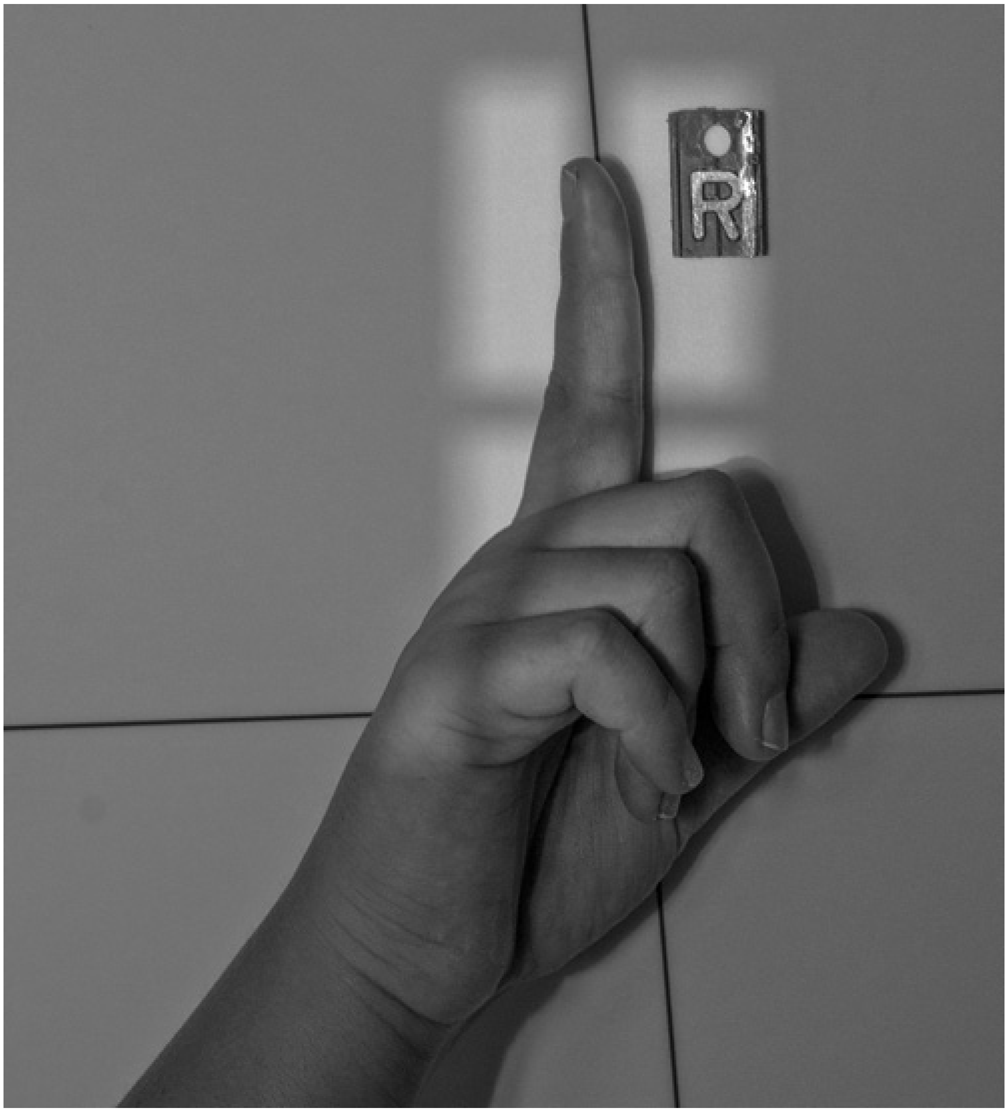


FIGURE 4.18 Proper patient positioning for lateral finger projection.

Inadequate Finger Rotation

Failing to properly rotate the finger to obtain a lateral projection results in an image that appears more like the PA oblique finger projection, with the concavity demonstrated on both sides of the middle and proximal phalangeal midshafts and the soft tissue width closer to twice as much on the anterior surface when compared with the posterior surface (**Fig. 4.21**).

FIGURE 4.19 Lateral finger projection without the unaffected fingers flexed enough to prevent soft tissue or bony superimposition of the affected digit's proximal phalanx.

FIGURE 4.20 Lateral finger projections demonstrating a proximal phalanx fracture that is stressed because of the positioning aide that was used to extend the finger and a distal fracture with appropriate use of the proximal phalanx positioning aide.

FIGURE 4.21 Lateral finger projection taken with insufficient finger obliquity.

Lateral Finger Analysis Practice

IMAGE 4.4

Analysis

Concavity is demonstrated on both sides of the middle and proximal phalangeal midshafts, indicating that the finger was not adequately rotated for this projection.

Correction

Increase the degree of finger rotation until the finger is in a lateral projection.

IMAGE 4.5

Analysis

The proximal aspect of the affected finger is obscured. The fifth finger was fanned posteriorly and the third finger was fanned anteriorly.

Correction

Draw all of the unaffected fingers into a fist.

Thumb: AP Projection

See **Table 4.5** and Figs. **4.22–4.24**.

Excessive Internal Thumb Rotation

When the thumb is rotated away from an AP projection, the amount of phalangeal midshaft concavity and soft tissue width increases on the side of the thumb that the anterior thumb surface rotates toward and decreases on the side that the posterior surface rotates toward. If the arm is internally rotated more than needed to bring the thumb in an AP projection, the anterior thumb surface and the greater phalangeal midshaft concavity is demonstrated on the side of the thumb positioned next to the hand on the projection (**Fig. 4.25**).

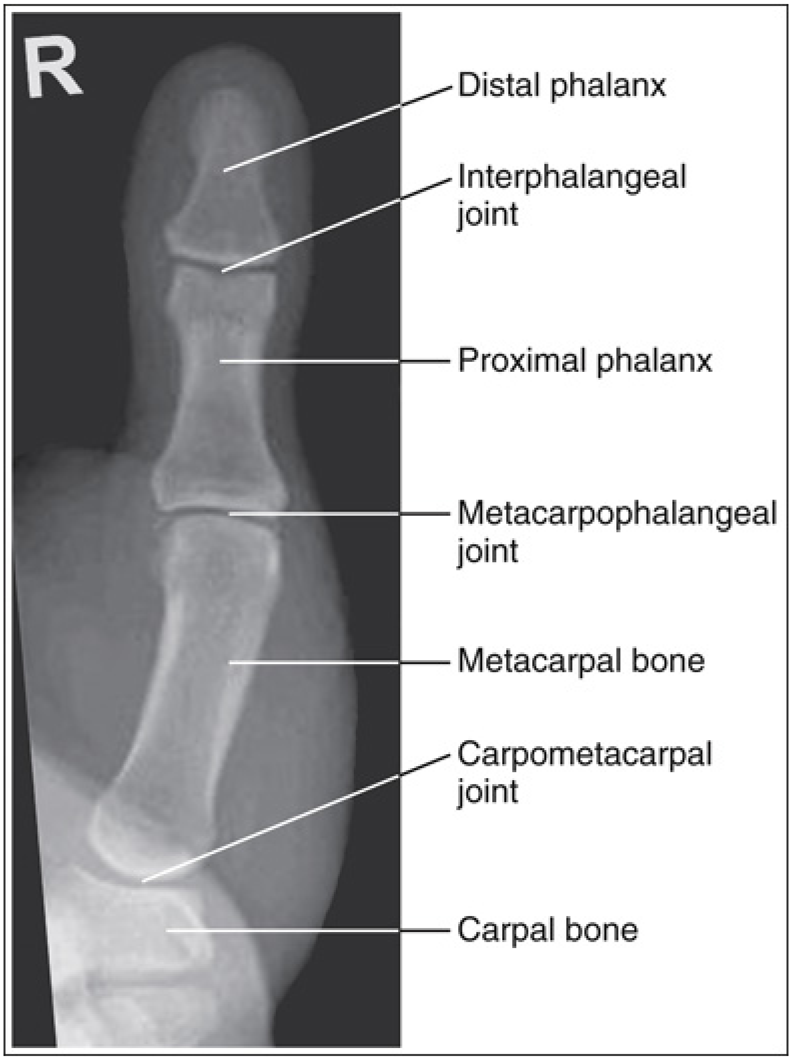


FIGURE 4.22 AP thumb projection with accurate positioning.

TABLE 4.5

AP, Anteroposterior; *CR*, central ray; *IP*, interphalangeal; *IR*, image receptor; *MCP*, metacarpophalangeal.

Insufficient Internal Thumb Rotation

Insufficient thumb rotation will demonstrate the medial palm soft tissue superimposing the MC. This mispositioning is seldom seen as it causes too much of the medial palm to overlap for the technologist to take the projection in this manner. If when positioning, the thumb is AP and there is too much of the medial palm overlap that cannot be removed without rotating the thumb, it would be best to obtain an AP thumb projection.

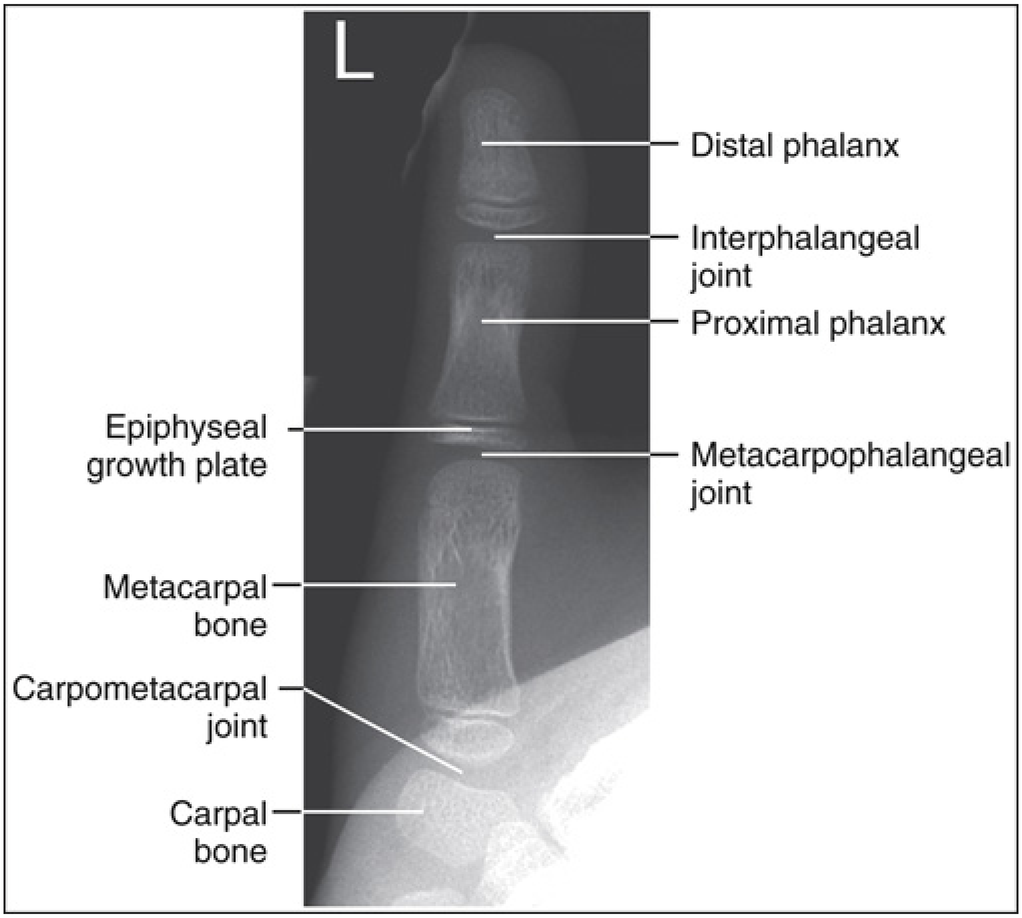


FIGURE 4.23 Accurately positioned pediatric PA thumb projection.

Open Joint Spaces and Unforeshortened Phalanges

Thumb flexion and extension (hitchhiker's thumb) foreshortens the phalanges and closes the IP joint spaces (**Fig. 4.26**). Failure to align the MC parallel with the IR will close the carpometacarpal (CM) joint.

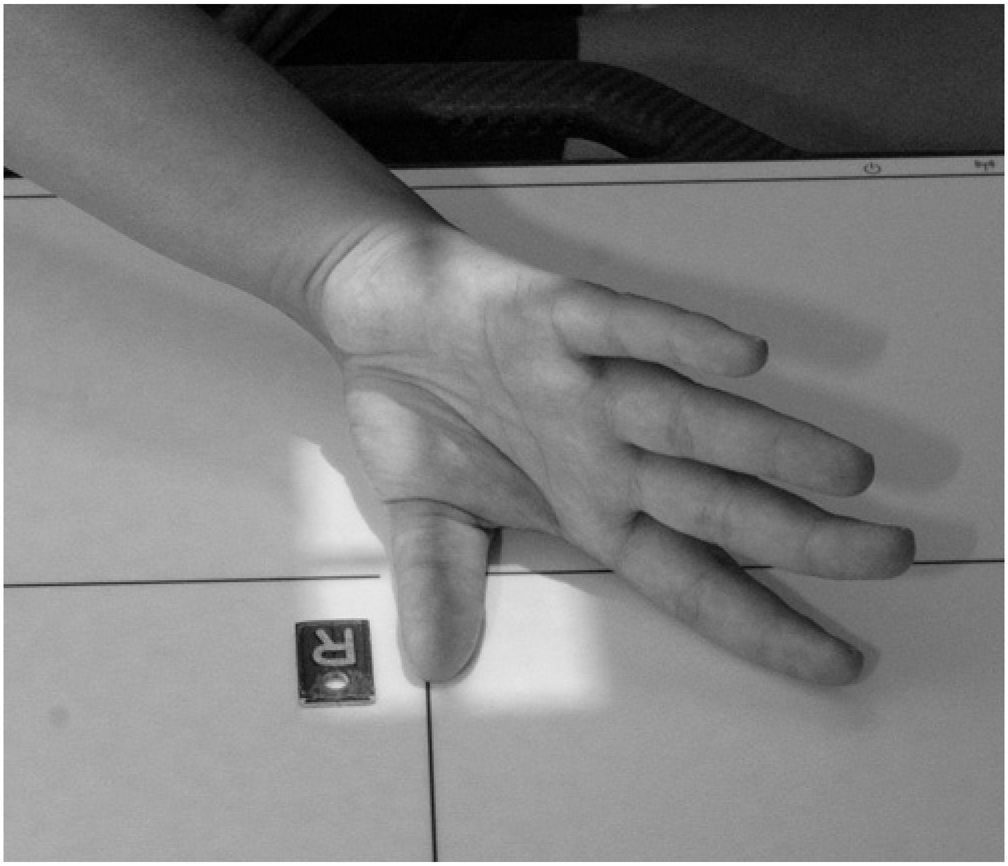


FIGURE 4.24 Proper patient positioning for AP thumb projection.

FIGURE 4.25 AP thumb projection taken with hand internally rotated too far.

Palmar Soft Tissue Overlap

If the medial surface of the palm is not drawn away from the thumb, the soft tissue and possibly the fourth and fifth MCs superimpose the proximal first MC and CM joint (**Fig. 4.27**).

FIGURE 4.26 AP thumb projection taken with the MP joint elevated off the IR and the distal thumb posteriorly extended.

FIGURE 4.27 AP thumb projection taken without the MCs and palmar surface drawn away from the thumb.

Thumb and Longitudinal Collimator Alignment

Aligning the long axes of the thumb and collimator's longitudinal light line enables you to collimate tightly without clipping the distal phalanx or proximal MC (**Fig. 4.28**).

FIGURE 4.28 AP thumb projection taken without the long axis of the thumb aligned with the long axis of the collimated field, causing the proximal MC and the CM joint to be clipped.

AP Thumb Analysis Practice

IMAGE 4.6

Analysis

The fifth MC and the medial palm soft tissue are superimposing the proximal first MC and CM joint. There is slightly more phalangeal concavity on the side of the thumb that is closest to the hand. The MCs and palmar surface have not been drawn away from the thumb and the thumb was internally rotated slightly more than needed.

Correction

Using the opposite hand, draw the medial side of the affected hand and palmar surface away from the thumb. Make sure that the thumb does not rotate from an AP projection with this movement.

Thumb: Lateral Projection

See **Table 4.6** and Figs. **4.29–4.31**.

Insufficient Hand Flexion

If the hand is not flexed enough to place the thumb in a lateral projection, the midshafts of the proximal phalanx and the MC will show some degree of concavity on both sides, indicating a PA oblique versus a lateral projection (**Fig. 4.32**).

Overflexion of Hand

Overflexion of the hand causes the second proximal MC to superimpose the first proximal MC and may cause the thumb to roll beyond a lateral and toward an AP oblique projection (**Fig. 4.33**).

Open Joint Spaces and Nonforeshortened Phalanges

Obtaining the projection with the finger flexed or tilted with the IR causes phalangeal foreshortening and closed joint spaces (**Fig. 4.34**).

Thumb Abduction

Whenever possible, the anatomic volume of interest is demonstrated without superimposition of any structure, or as few as possible. Failure to abduct the thumb results in increased first proximal MC superimposition of the first CM joint (**Fig. 4.35**).

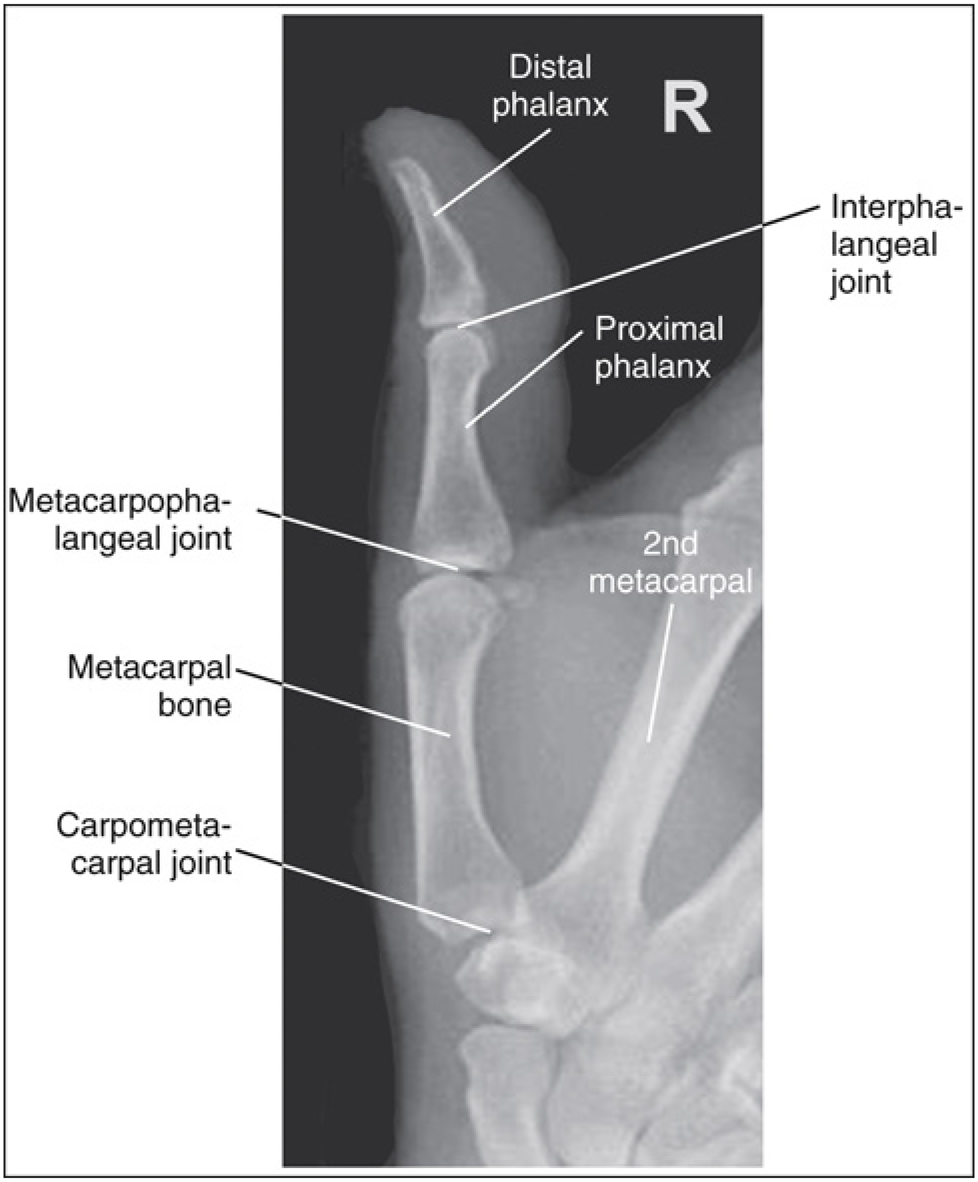


FIGURE 4.29 Lateral thumb projection with accurate positioning.

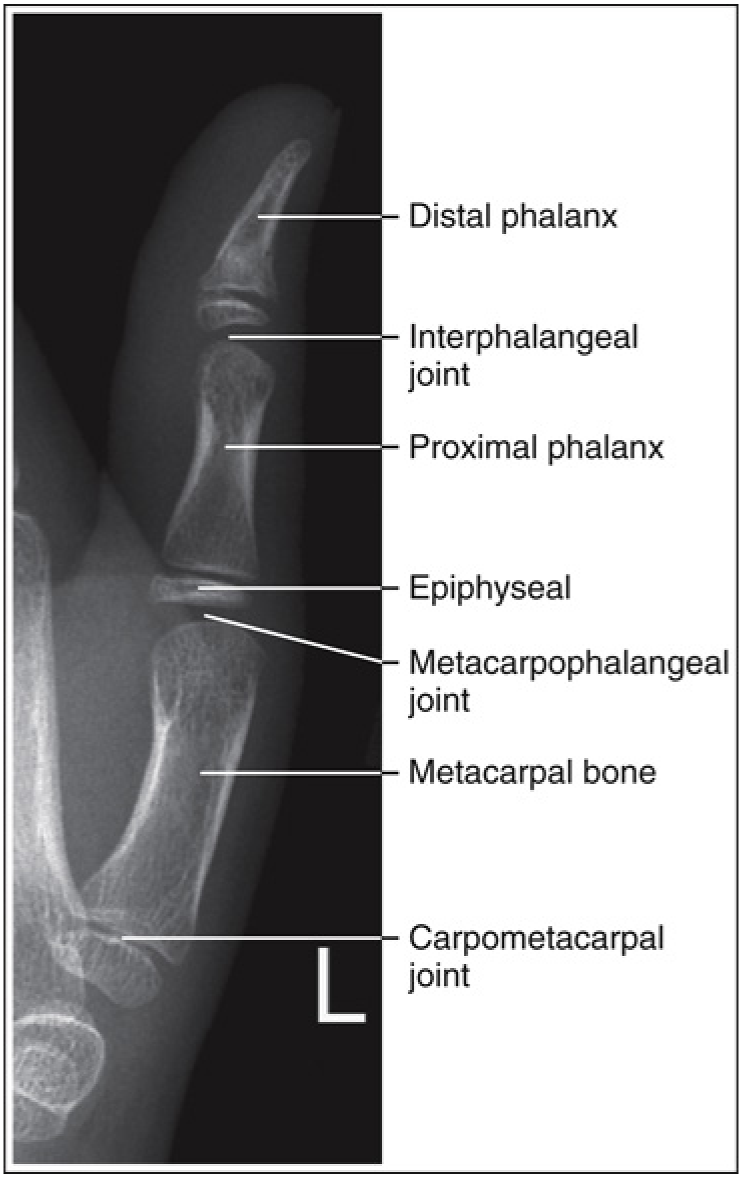


FIGURE 4.30 Accurately positioned pediatric lateral thumb projection.

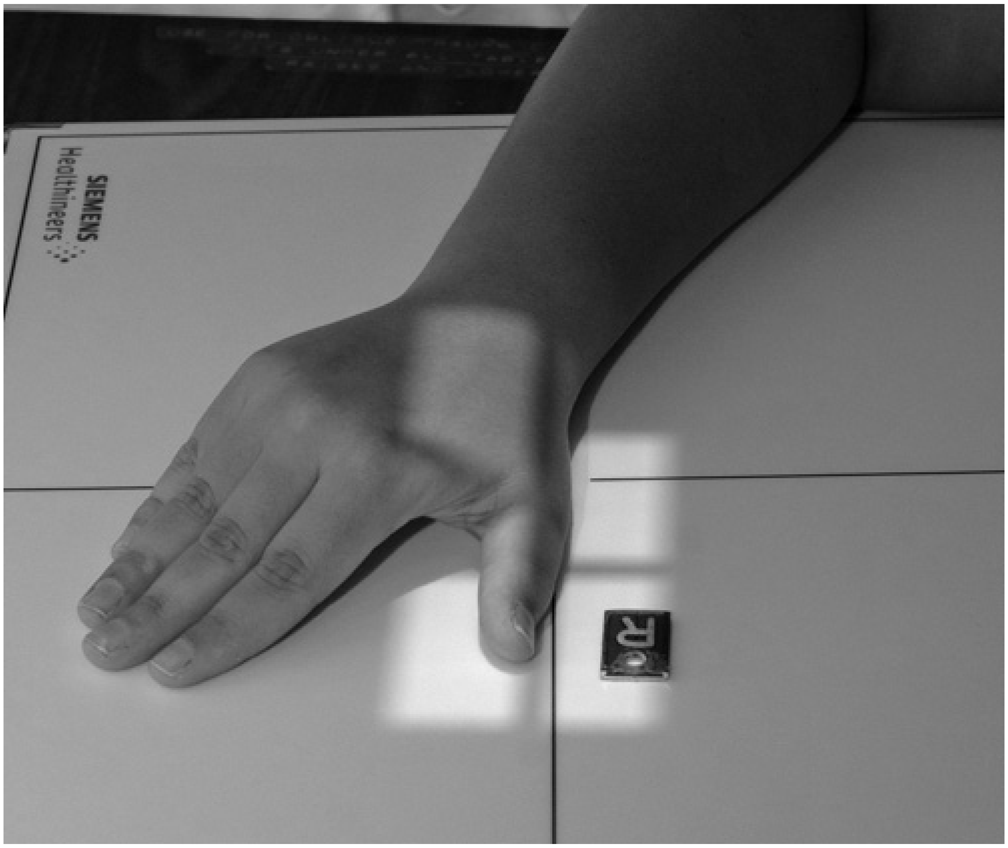


FIGURE 4.31 Proper patient positioning for lateral thumb projection.

FIGURE 4.32 Lateral thumb projection taken without adequate hand flexion.

FIGURE 4.33 Lateral thumb projection taken with the hand over-flexed, causing the second proximal MC to superimpose the first proximal MC.

FIGURE 4.34 Lateral thumb projection taken with the distal phalanx flexed, closing the distal interphalangeal (DIP) joint space.

FIGURE 4.35 Lateral thumb projection taken without the thumb abducted.

TABLE 4.6

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MCP*, metacarpophalangeal.

Lateral Thumb Analysis Practice

IMAGE 4.7

Analysis

The midshafts of the proximal phalanx and the MC demonstrate some degree of concavity on both sides, indicating a PA oblique projection. The hand was not flexed enough.

Correction

Flex the hand until the thumb rolls to a lateral projection with the thumbnail in profile.

Thumb: PA Oblique Projection

See **Table 4.7** and Figs. **4.36**–**4.38**.

Excessive Thumb Rotation

If the hand is not placed flat against the IR, but is allowed to flex, the thumb rotates closer to a lateral projection. Such positioning can be identified on a projection by noting the increase in midshaft concavity and soft tissue width seen on the anterior thumb surface and the decrease in concavity and soft tissue width seen on the posterior thumb surface (**Fig. 4.39**).

Open Joint Spaces and Nonforeshortened Phalanges

If the hand is not positioned against the IR, but instead is rotated medially, it causes the thumb to tilt downwardly, the IP and MCP joint spaces to be closed, and the phalanges to be foreshortened (**Fig. 4.40**).

Thumb and Longitudinal Collimator Alignment

Aligning the long axes of the thumb and collimator's longitudinal light line allows for tight collimation without clipping the distal phalanx or proximal MC (**Fig. 4.41**).

FIGURE 4.36 PA oblique thumb projection with accurate positioning.

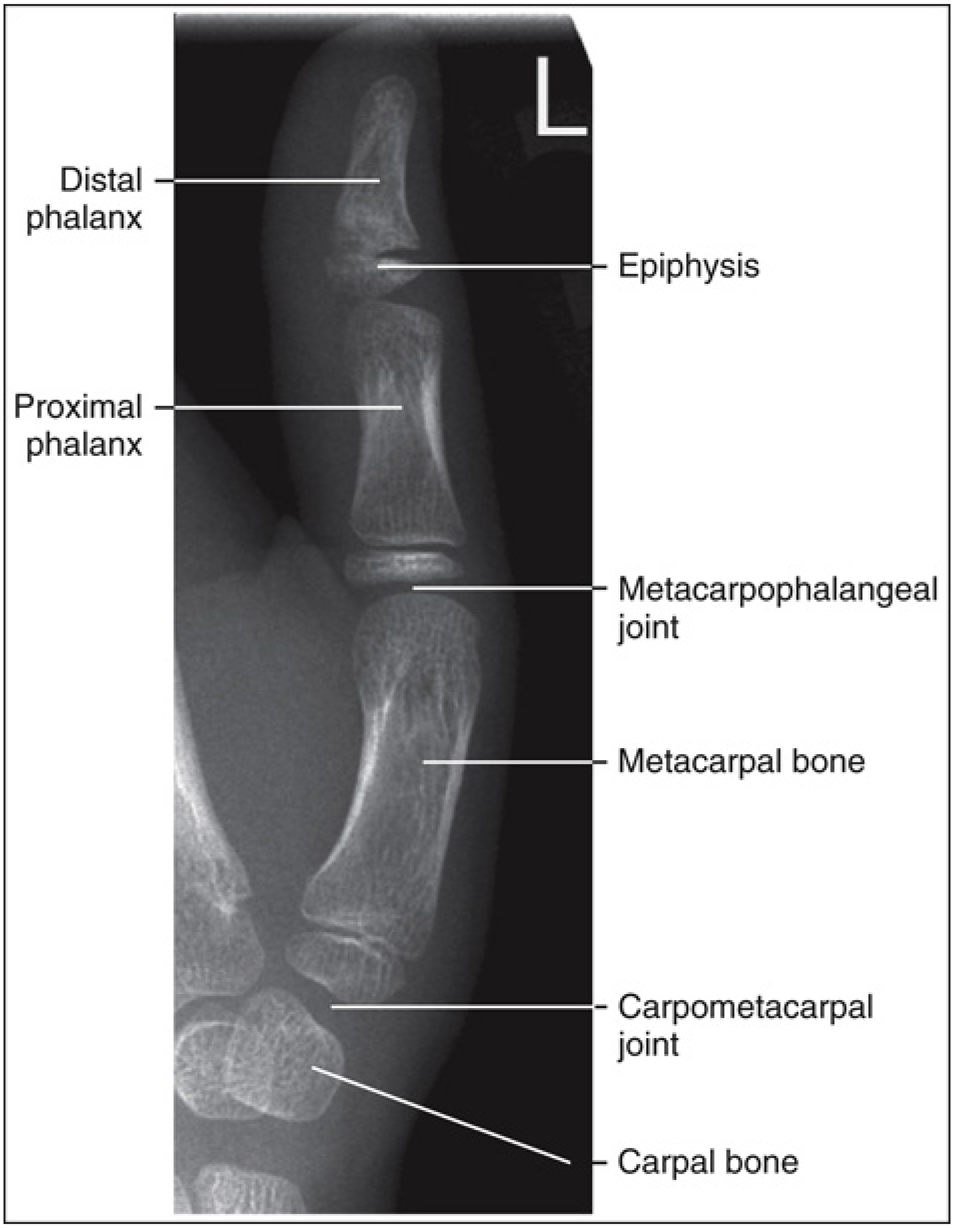


FIGURE 4.37 Accurately positioned pediatric PA oblique thumb projection.

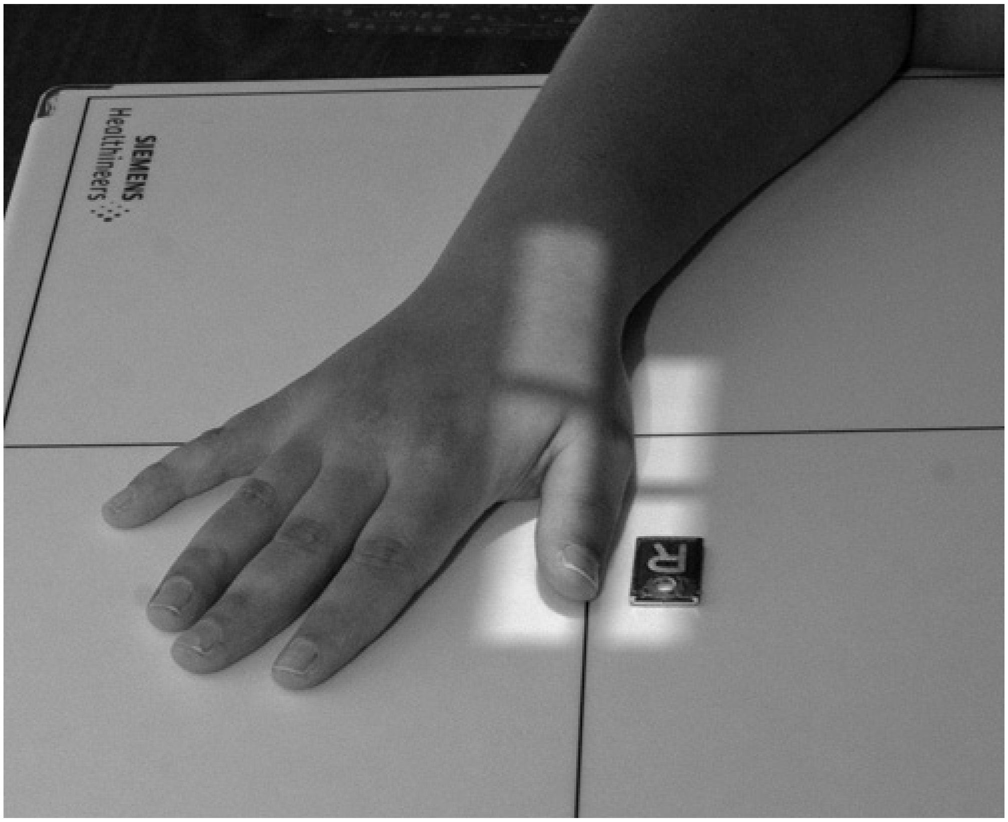


FIGURE 4.38 Proper patient positioning for PA oblique thumb projection.

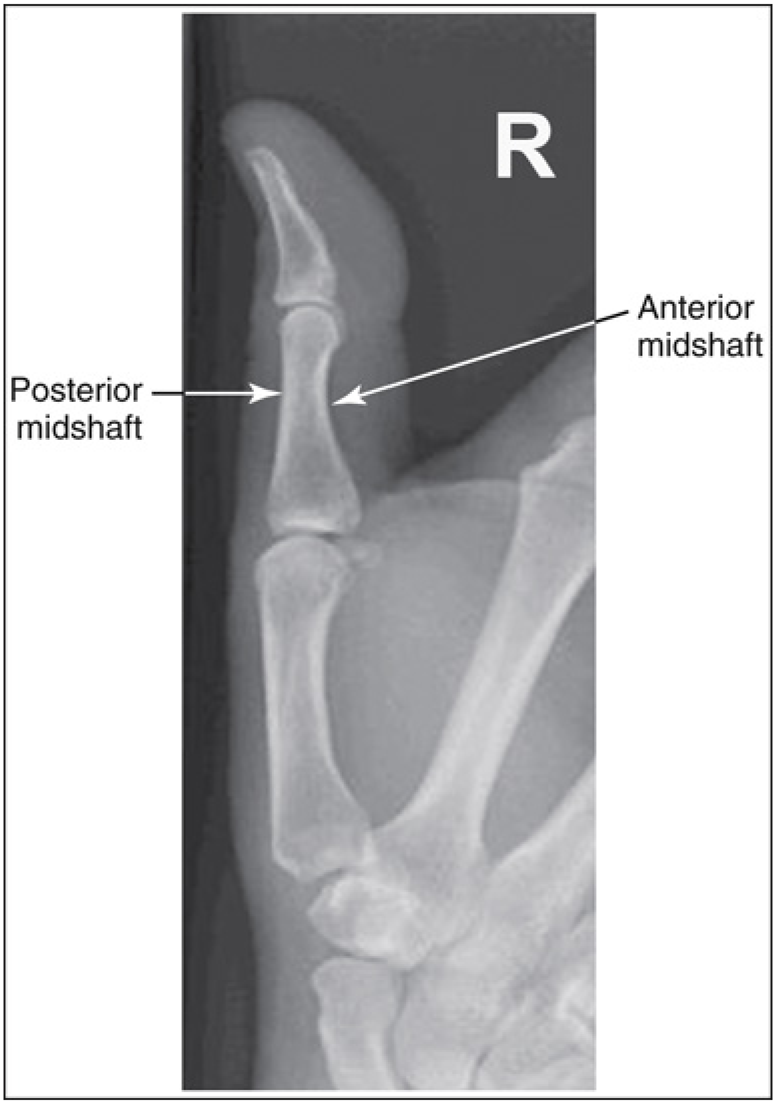


FIGURE 4.39 PA oblique thumb projection taken without the palm placed flat against the IR, causing thumb to be positioned at more than 45 degrees of obliquity.

FIGURE 4.40 PA oblique thumb projection taken without the palmar surface and thumb against the IR.

FIGURE 4.41 PA oblique thumb projection taken without the long axis of the thumb aligned with the long axis of the collimated field, causing the proximal MC and the CM joint to be clipped.

TABLE 4.7

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MCP*, metacarpophalangeal.

PA Oblique Thumb Analysis Practice

IMAGE 4.8

Analysis

The IP and MCP joints are closed, and the phalanges are foreshortened. The palm surface was not positioned flat against the IR, and the thumb was tilting down toward the IR.

Correction

Place the palmar surface and thumb flat against the IR.

Hand: PA Projection

See **Table 4.8** and Figs. **4.42** and **4.43**.

External Hand Rotation

If the hand is not fully extended and brought flat against the IR but is slightly flexed, it will typically rotate externally. External hand rotation causes narrowing or slight superimposition of the third through fifth MC heads and unequal soft tissue thickness and midshaft concavity on the sides of the phalanges. The MCs also show unequal midshaft concavity and spacing (**Fig. 4.44**).

Internal Hand Rotation

Internal rotation of the hand is seldom a problem because the thumb prevents this movement.

Thumb and Finger Separation

Keeping the fingers placed close together but without superimposition prevents soft tissue overlap and allows for tighter collimation (**Fig. 4.45**). When the thumb is abducted instead of remaining at a close distance from the hand, the CR needs to be moved toward the second MCP joint to transversely collimate to within 0.5 inch (1.25 cm) from the first and fifth digits' skin line (**Fig. 4.46**).

TABLE 4.8

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MCP*, metacarpophalangeal; *PA*, posteroanterior.

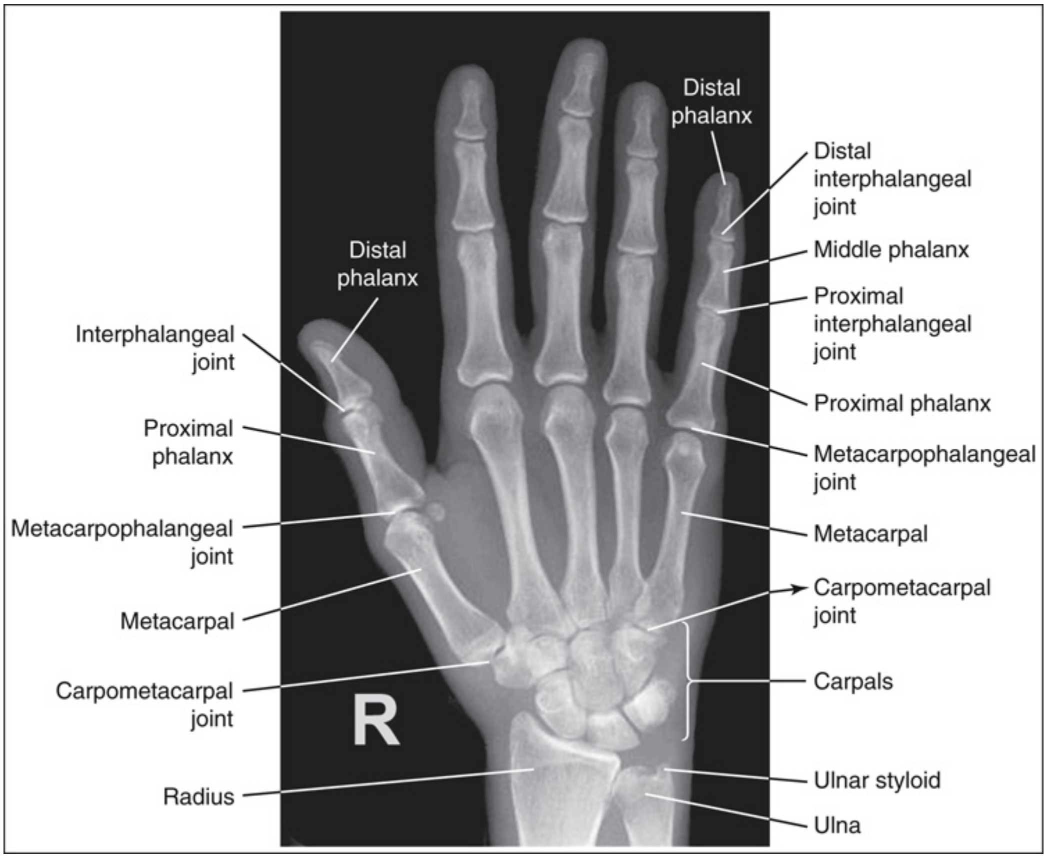


FIGURE 4.42 PA hand projection with accurate positioning.

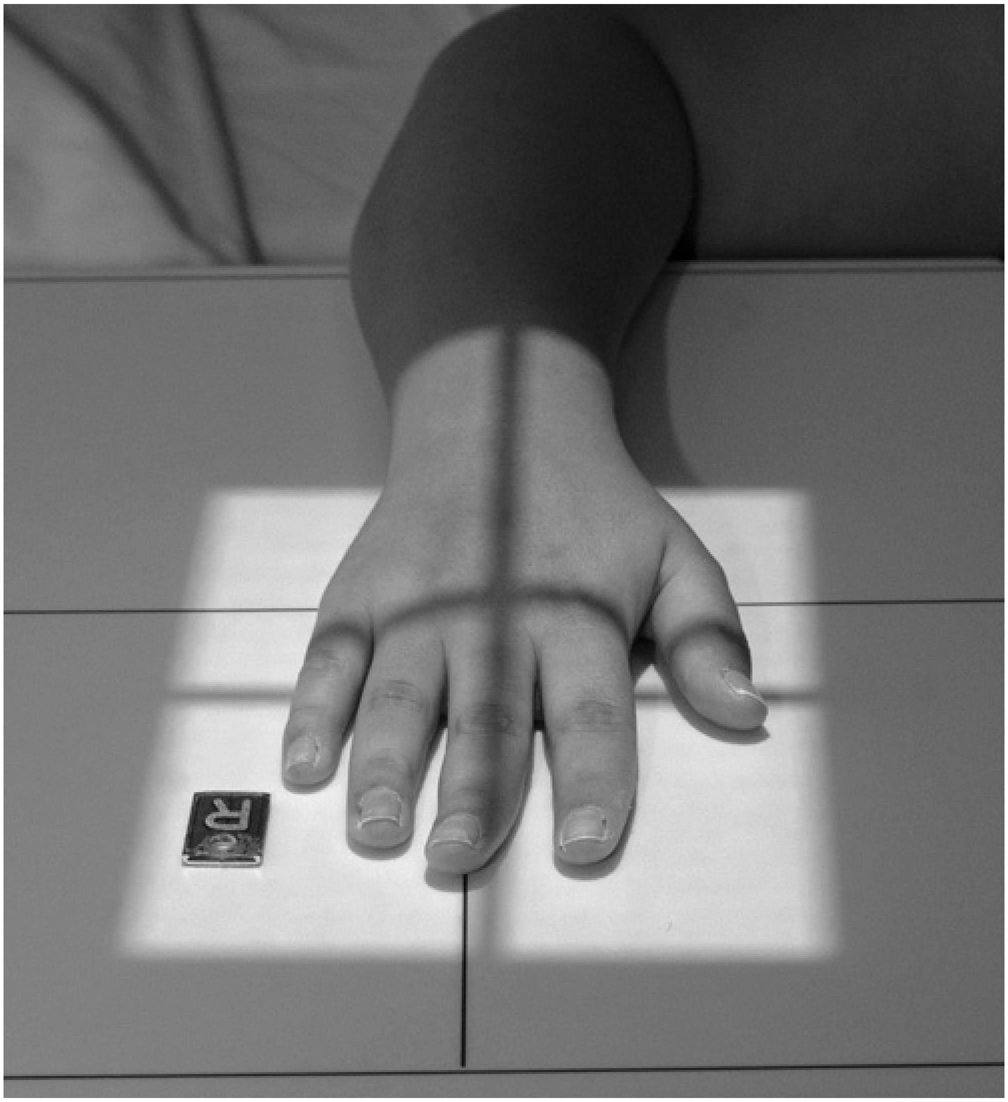


FIGURE 4.43 Proper patient positioning for PA hand projection.

FIGURE 4.44 PA hand projection taken in external rotation.

FIGURE 4.45 PA hand projection with the thumb and fingers demonstrating excessive separation.

FIGURE 4.46 PA hand projection with the thumb positioned too far away from the hand, causing the CR to be centered on the second MC head.

FIGURE 4.47 PA hand projection taken with the hand and fingers flexed.

Open Joint Spaces, and Nonforeshortened Phalanges and Metacarpals

Flexion of the hand causes poor alignment of the IP and CM joint spaces, phalanges, and MCs with the IR and CR, resulting in closed IP and CM joint spaces, and foreshortened phalanges and MCs (**Fig. 4.47**). The position of the thumb also changes to closer to or to a lateral projection as the degree of hand flexion increases.

Pediatric Bone Age Assessment

A pediatric PA bone age hand is taken to assess the skeletal versus the chronologic age of a child. Because bones develop in an orderly pattern, skeletal age may be assessed from infancy through adolescence. Illness, metabolic or endocrine dysfunction, and taking certain types of medications and therapies are all reasons why a pediatric skeletal and chronologic age may not correspond. A left PA hand and wrist is typically the projection of choice because bony developmental changes are readily visible and easily evaluated. For skeletal age to be evaluated, the phalanges, MCs, carpals, and distal radius and ulna must be included in their entirety (**Fig. 4.48**).

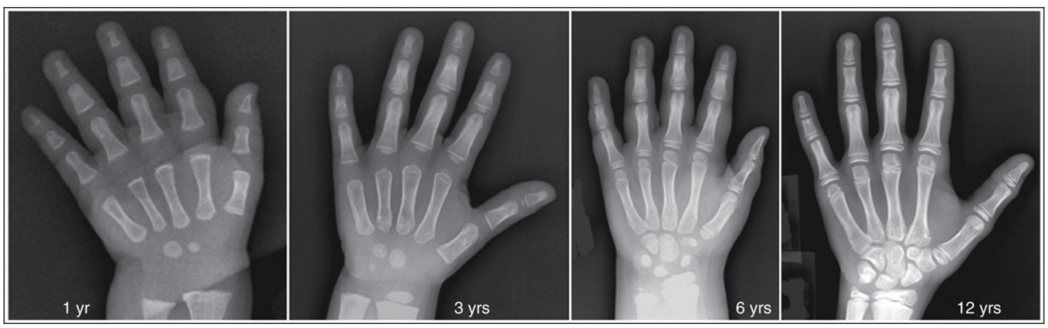


FIGURE 4.48 Pediatric PA hand projections taken to assess bone age.

PA Hand Analysis Practice

IMAGE 4.9

Analysis

There is unequal midshaft concavity on either side of the phalanges and MCs, and uneven spacing of the MC heads. The hand was in slight external rotation. Less than 1 inch (2.5 cm) of the distal forearm is included on the projection.

Correction

Internally rotate the hand and place the palm and fingers flat against the IR. Open the longitudinal collimation 0.5 inch (1.25 cm).

IMAGE 4.10

Analysis

The IP and CM joints are closed, and the phalanges and MCs are foreshortened. The thumb demonstrates a lateral projection. The hand and fingers were flexed for this projection.

Correction

Fully extend the hand and fingers, and place them flat against the IR. If the patient is unable to extend the hand and fingers, position the hand in an AP projection with the MC aligned parallel with the IR. If the phalanges are of

interest, tilt the hand until the bony structure of greatest interest is parallel with the IR (see **Fig. 4.8**).

IMAGE 4.11

Analysis

The thumb was abducted and the CR was centered to the second MCP joint.

Correction

Position the thumb closer to the hand and center the CR to the third MCP joint.

Hand: PA Oblique Projection (Lateral Rotation)

See **Table 4.9** and Figs. **4.49** and **4.50**.

Insufficient Hand Obliquity

If the PA oblique hand is obtained with less than 45 degrees of obliquity, the MC relationship is similar to that of a PA projection of the hand with the midshafts of the MCs closer to being evenly spaced, and the MC heads seen with less or without superimposition (**Fig. 4.51**).

Excessive Hand Obliquity

An accurate PA oblique hand demonstrates a small space between the fourth and fifth MC midshafts. If the hand is rotated more than 45 degrees, this space is obscured and the fourth and fifth MC midshafts demonstrate some degree of superimposition (**Fig. 4.52**).

FIGURE 4.49 PA oblique hand projection with accurate positioning.

TABLE 4.9

CR, Central ray; *IR*, image receptor; *PA*, posteroanterior.

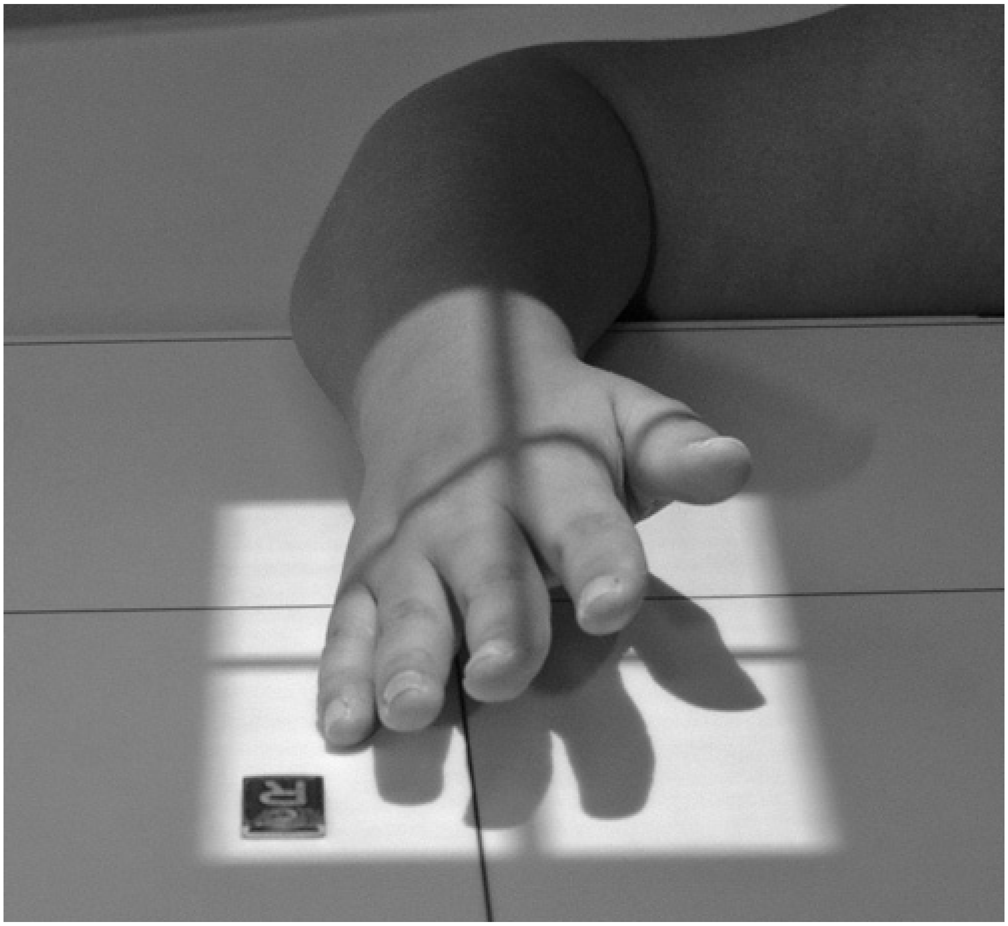


FIGURE 4.50 Proper patient positioning for PA oblique hand projection with extended fingers.

FIGURE 4.51 PA oblique hand projection taken with inadequate hand obliquity.

Thumb and Finger Separation

Keeping the fingers placed close together but without superimposition prevents soft tissue overlap and allows for tighter collimation (**Fig. 4.53**). When the thumb is abducted the CR needs to be moved toward the second MCP joint to transversely collimate to within 0.5 inch (1.25 cm) from the first and fifth digits' skin line (**Fig. 4.54**).

Open IP and MCP Joint Spaces and Nonforeshortened Phalanges and Metacarpals

A PA oblique hand projection obtained with the fingers flexed toward the IR will demonstrate closed IP and MCP joint spaces and foreshortened phalanges (**Figs. 4.55**).

FIGURE 4.52 PA oblique hand projection taken with more than 45 degrees of obliquity.

FIGURE 4.53 PA oblique hand projection taken without the fingers spread apart, causing soft tissue and bony structures of adjacent digits to overlap.

FIGURE 4.54 PA oblique hand projection with thumb positioned too far away from the hand and taken with CR centered on second MC head.

FIGURE 4.55 PA oblique hand projection taken without the fingers positioned parallel with the IR.

PA Oblique Hand Analysis Practice

IMAGE 4.12

Analysis

The midshaft of the fourth and fifth MCs are superimposed. The hand was placed at more than 45 degrees of obliquity. The phalanges are foreshortened, and the IP joint spaces are closed. The fingers were flexed toward the IR.

Correction

Internally rotate the hand until the MCs and IR form a 45-degree angle and extend the fingers, placing them parallel with the IR.

IMAGE 4.13

Analysis

The thumb was abducted and the CR was centered on the second MCP joint.

Correction

Position the thumb at a closer distance to the hand and center to the third MCP joint. Increase collimation.

Hand: “Fan” Lateral Projection (Lateromedial)

See **Table 4.10** and Figs. **4.56** and **4.57**.

External Hand Rotation

If the MC midshafts are not superimposed and the fifth MC is demonstrated anterior to the second through fourth MCs, the hand was externally rotated (**Fig. 4.58**). The fifth MC can be identified by its length; it is the shorter of the second through fifth MCs.

Internal Hand Rotation

If the MC midshafts are not superimposed and the second MC is demonstrated anterior to the third through fifth MCs, the hand was internally rotated (Figs. **4.59** and **4.60**). The second MC can be identified by its length; it is the longer of the second through fifth MCs.

FIGURE 4.56 Lateral hand projection with accurate positioning.

TABLE 4.10

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MCP*, metacarpophalangeal; *PA*, posteroanterior.

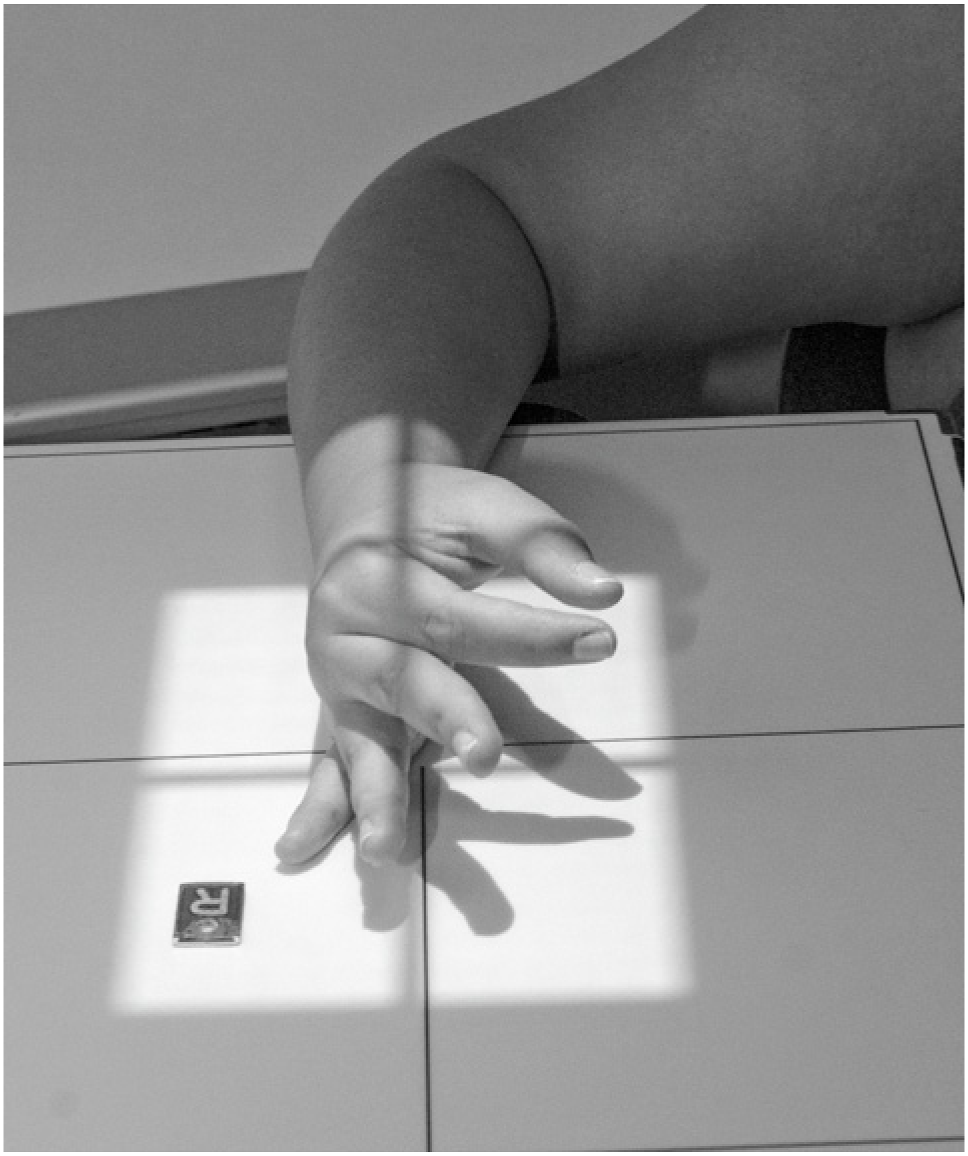


FIGURE 4.57 Proper patient positioning for lateral hand projection.

FIGURE 4.58 Lateral hand projection taken with the hand in external rotation and demonstrating the OK sign.

FIGURE 4.59 Lateral hand projection taken with the hand in internal rotation.

Fanned Fingers

To demonstrate the fingers without superimposition on a lateral hand projection, they are fanned. The amount of finger separation obtained depends on the patient's mobility. Radiolucent support devices are available to help maintain proper positioning. When the fingers are fanned they can be individually studied. If the fingers are not adequately separated they superimpose one another on the projection (**Fig. 4.61**).

Using the OK Sign to Fan Fingers

Asking the patient to make the OK sign is a reliable method of explaining to the patient how to fan the fingers, although before taking the exposure have the patient release the finger and thumb slightly to prevent them from superimposing or being foreshortened (**Fig. 4.62**).

Lateral Hand in Extension

Foreign bodies of the palm may be better localized when the lateral hand projection is taken with the hand and fingers in extension. The image analysis guidelines for the extended lateral hand projection will be the same as for the fan lateral projection, except that the second through fifth fingers will be superimposed (**Fig. 4.63**).

FIGURE 4.60 Pediatric lateral hand projection taken with the hand in slight internal rotation.

Lateral Hand in Flexion

A lateral hand projection obtained with the hand in flexion may cause less stress on a fractured MC. The image analysis guidelines for the flexed lateral hand projection will be the same as for the fan lateral projection, except that the hand will be flexed and the second through fifth fingers will be superimposed (**Fig. 4.64**).

Open Joint Spaces and Nonforeshortened Phalanges and Metacarpals

If the fingers or thumb are not aligned parallel with the IR, the joint spaces are closed and the phalanges and MCs are foreshortened (see **Figs. 4.59** [second finger], **4.61** [thumb], and **4.62** [second finger]).

FIGURE 4.61 Lateral hand projection obtained without fanning of the fingers or placing the thumb parallel with the IR.

FIGURE 4.62 Fanning fingers using the OK sign.

FIGURE 4.63 Lateral hand projection taken with the hand and fingers in full extension.

FIGURE 4.64 Lateral hand projection taken with the hand and fingers flexed.

Lateral Hand Analysis Practice

IMAGE 4.14

Analysis

The second through fifth MC midshafts are not superimposed, and the shortest (fifth) MC is anterior to the second through fourth MCs. The hand was externally rotated.

Correction

Internally rotate the hand until the MCs are superimposed.

IMAGE 4.15

Analysis

The digits are superimposed and the thumb and first finger are touching. Fingers were not fanned. The fifth MC is anterior to the second through fourth MCs. The hand was in slight external rotation.

Correction

Separate the thumb and first finger and fan the second and third fingers anteriorly and the fourth and fifth posteriorly, separating the fingers as far

apart as possible without superimposing the thumb. Internally rotate the hand until the MCs are superimposed.

Wrist: PA Projection

See **Table 4.11** and Figs. **4.65** and **4.66**.

Ulnar Styloid Placement

Humeral epicondyle positioning with the IR determines the placement of the ulnar styloid on wrist projections (**Fig. 4.67**).

- *Humeral epicondyles aligned perpendicular to IR* demonstrates the ulnar styloid in profile, medially.
- *Humeral epicondyles aligned parallel to IR* demonstrates the ulnar styloid projecting distal to the ulnar head midline.
- *Humeral epicondyles in and internal AP oblique projection with IR* demonstrates the ulnar styloid between the previous two positions.

Scaphoid Fat Stripe Visualization

The scaphoid fat stripe is one of the soft tissue structures that is visible on properly positioned PA wrist projections (**Fig. 4.68**). It is convex in shape and is located just lateral to the scaphoid in an uninjured wrist. A change in the convexity of this stripe may indicate to the reviewer the presence of joint effusion or of a radial side fracture of the scaphoid, radial styloid process, or proximal first MC. Failing to set the appropriate technical factors as described in **Chapter 2** and to obtain a true PA projection may result in obscuring this stripe.

TABLE 4.11

CR, Central ray; *IR*, image receptor; *PA*, posteroanterior.

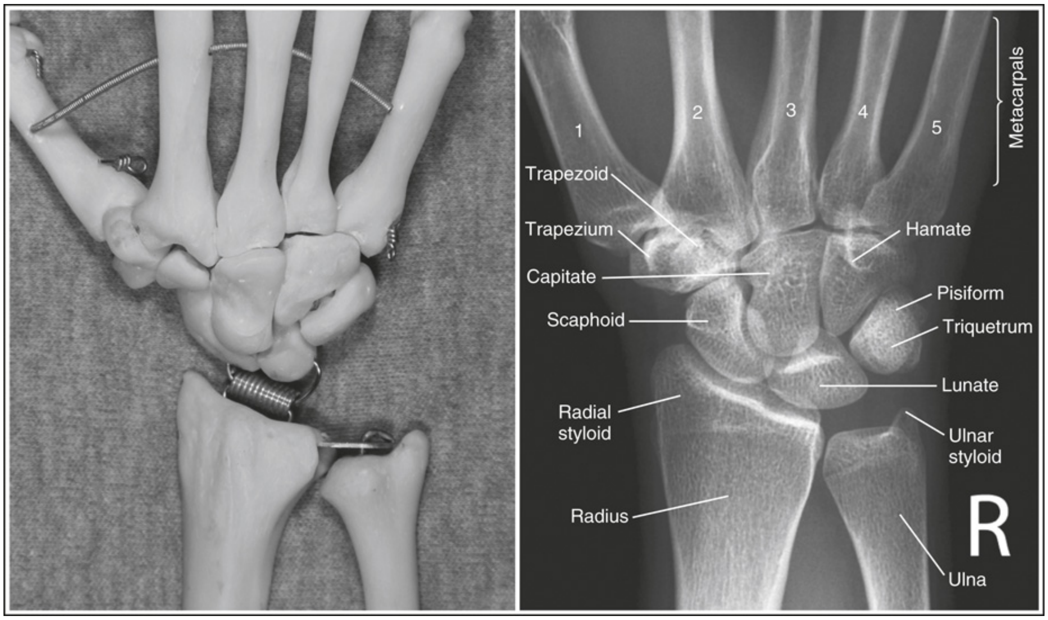


FIGURE 4.65 PA wrist projection with accurate positioning.

FIGURE 4.66 Proper patient positioning for PA wrist projection.

External Wrist Rotation

Upon external wrist rotation (**Fig. 4.69**) the:

- Medially located carpal bones and MC bases demonstrate increased superimposition and decreased carpal joint space visualization,
- Laterally located carpal bones and MC bases demonstrate less superimposition and increased carpal joint space visualization, and

• Radioulnar articulation closes.

Internal Wrist Rotation

Upon internal wrist rotation (**Fig. 4.70**) the:

- Laterally located carpal bones and MC bases demonstrate increased superimposition and decreased carpal joint space visualization,
- Pisiform and hamate hook demonstrate increased visibility, and
- Radioulnar articulation closes.

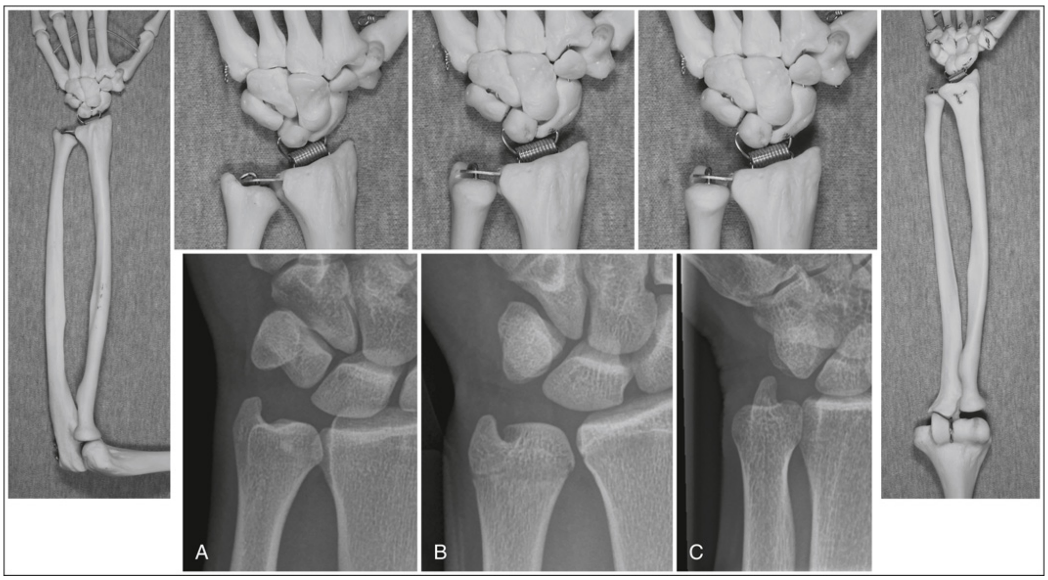


FIGURE 4.67 Wrist projections demonstrating the relationship between humeral epicondyle positioning and ulnar styloid demonstration. (A) Humeral epicondyles aligned perpendicular to IR. (B) Humeral epicondyles in an internal AP oblique projection with IR. (C) Humeral epicondyles aligned parallel with IR.

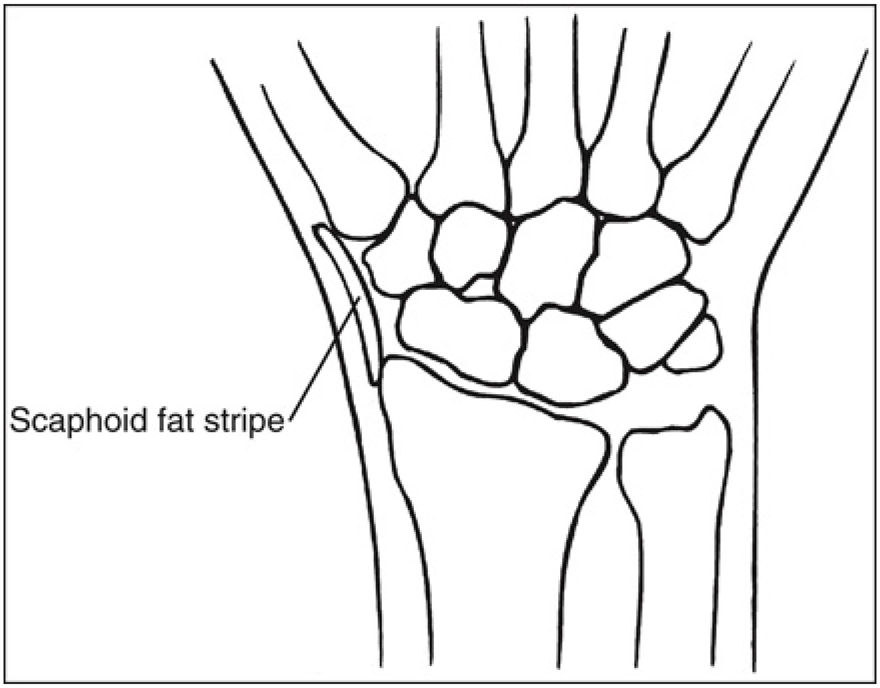


FIGURE 4.68 Location of scaphoid fat stripe.

Forearm Parallelism: Radioscaphoid and Radiolunate Joints and Distal Radius

The distal end of the radius is concave and slants approximately 11 degrees from posterior to anterior (**Fig. 4.71**). When the forearm is positioned parallel with the IR for a PA wrist projection, the slant of the distal radius causes the posterior radial margin to project slightly distal to the anterior radial margin, obscuring the radioscaphoid and radiolunate joints. If the forearm is not placed parallel with the IR the wrist will be extended or flexed instead of the desired neutral.

FIGURE 4.69 PA wrist projection taken with the wrist in external rotation.

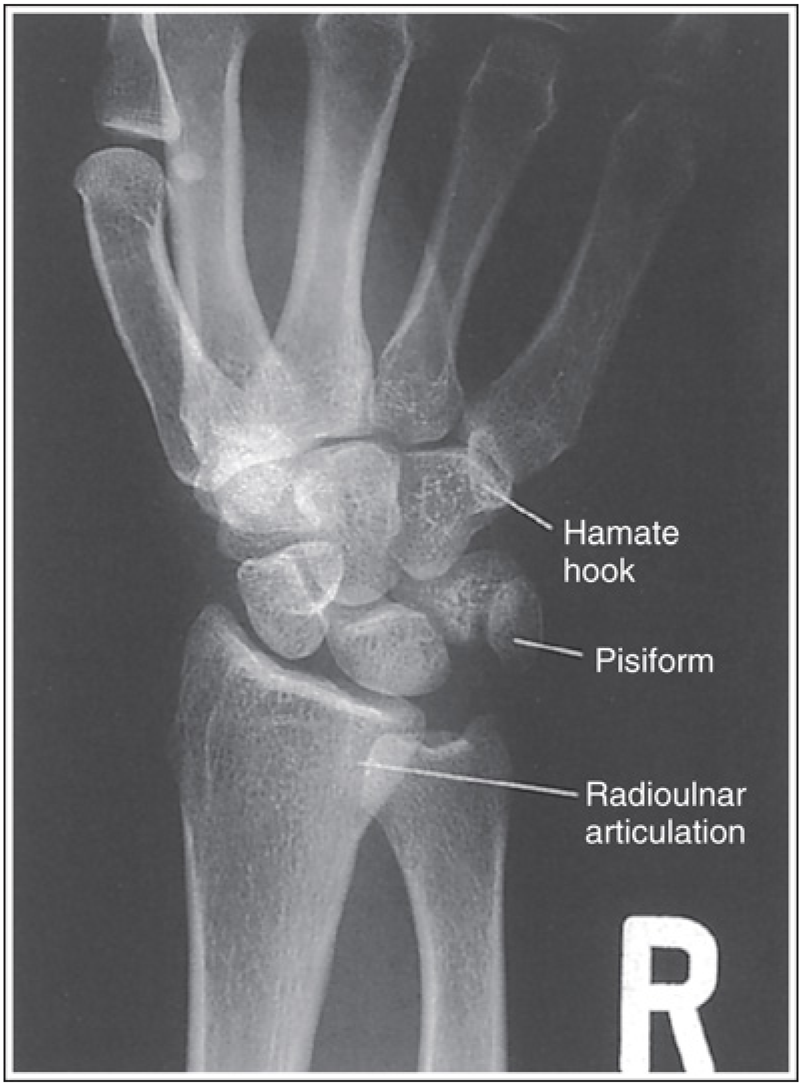


FIGURE 4.70 PA wrist projection taken with the wrist in internal rotation.

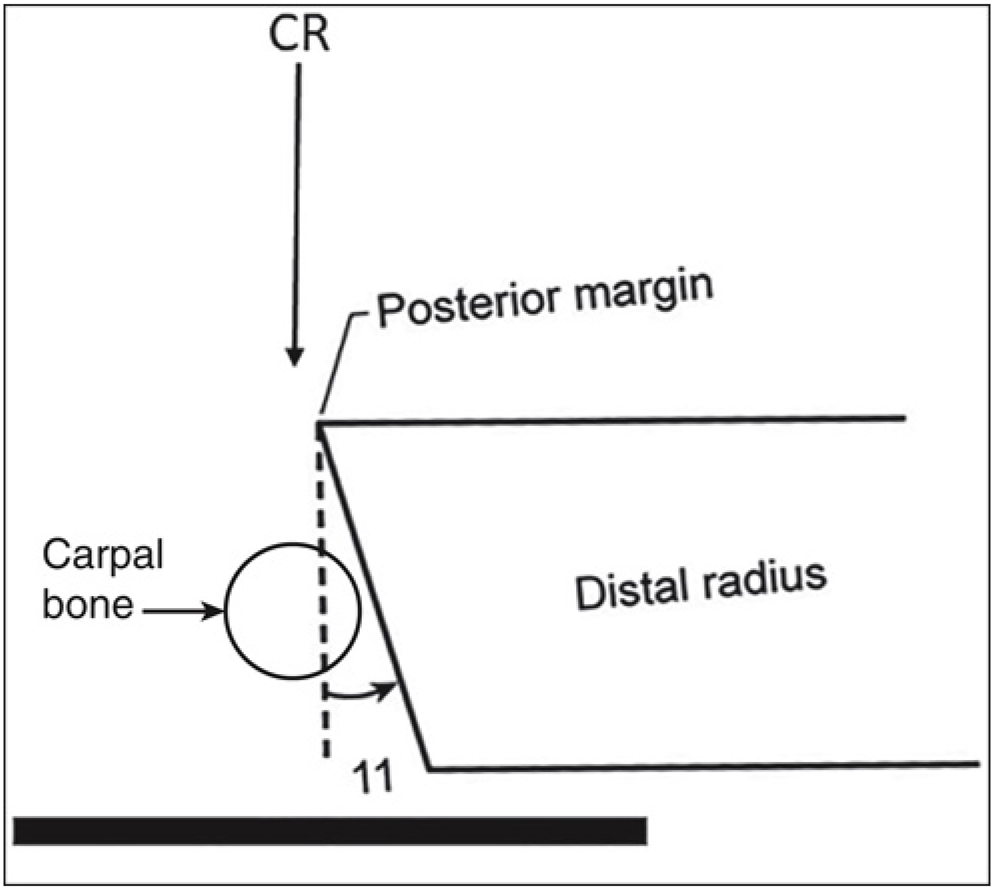


FIGURE 4.71 When the forearm is aligned parallel with the IR the radioscaphoid and radiolunate joints are closed because of the 11-degree slant of the distal radius.

Wrist Extension: Elevated Proximal Forearm

If the proximal forearm is elevated higher than the distal forearm the wrist is extended and the resulting projection will demonstrate the posterior radial margin superimposing more than one-fourth of the lunate (see Figs. **4.69** and **4.72**). This error occurs on patients with large muscular or thick proximal forearms and can be avoided by allowing the proximal forearm to hang off the IR or imaging table enough that it can be lowered to bring the forearm parallel with the IR.

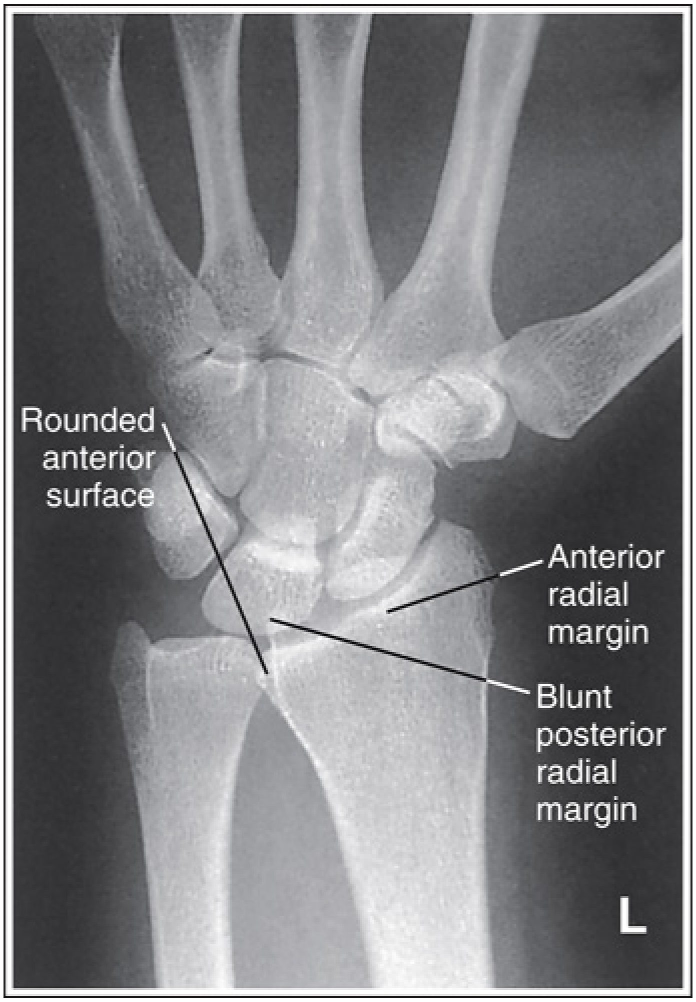


FIGURE 4.72 PA wrist projection taken with the proximal forearm positioned higher than the distal forearm.

Wrist Flexion: Depressed Proximal Forearm

If the proximal forearm is depressed lower than the distal forearm, causing wrist flexion, the posterior radial margin will superimpose less than one-fourth of the lunate. With enough proximal forearm depression the anterior and posterior radial margins will superimpose, providing open radioscaphoid and radiolunate joint spaces (**Fig. 4.73**). This may be desired

if a fracture of the scaphoid or lunate is present and can be accomplished by placing the proximal forearm 5 to 6 degrees lower than the distal forearm.

Identifying the Posterior and Anterior Distal Radial Margins

To identify the posterior and anterior radial margins from each other on a PA projection, view the distal radioulnar articulation. The posterior edge of this surface is blunt, whereas the anterior edge is rounded (see **Fig. 4.72**). Also notice that with external wrist rotation the posterior aspect of the radius and the ulna are superimposed (see **Fig. 4.69**) and with internal rotation the anterior aspect of the radius and the ulna are superimposed.

FIGURE 4.73 PA wrist projection taken in wrist flexion caused by the proximal forearm being positioned lower than the distal forearm.

Wrist Flexion and Extension

To understand how the wrist's position changes when the hand is placed against the IR and flexed, view your own wrist in a PA projection with the hand extended flat against a hard surface. In this position the wrist is slightly flexed. Next, begin slowly flexing your hand and notice how the wrist moves from a flexed to an extended position with increased hand

flexion. The drawings of the scaphoid, capitate, and lunate bones in **Fig. 4.74** illustrate how the position of these carpal bones also varies with this wrist flexion and extension. When the wrist is in a neutral position, the CM joint spaces are aligned parallel with the x-ray beams that record them and are demonstrated as open spaces (**Fig. 4.75**).

Hand Flexion: Metacarpal Angle and CM Joint Openness

Because the fingers and the MCs are different lengths and the hand contour tends to curve anteriorly, the MCs need to be placed at different angles with the IR to open the CM joints. To open the second and third CM joints, the second MC is placed at a 10-degree angle with the IR and to open the fourth and fifth CM joints, the fifth MC is placed at a 15-degree angle with the IR. To obtain a PA wrist projection that demonstrates all of the CM joints as open spaces, the patient would have to be able to position the second through fifth (MP) knuckles on the same transverse level. Not an easy task. **Fig. 4.65** demonstrates a patient who was able to accomplish this goal. If the patient is unable to do this task, place the MCs at the angle needed to open the CM joint(s) closest to the injury. Position the second MC at 10 degrees to open the second and third CM joints (**Fig. 4.76**) and position the fifth MC at 15 degrees to open the fourth and fifth CM joints (**Fig. 4.77**).

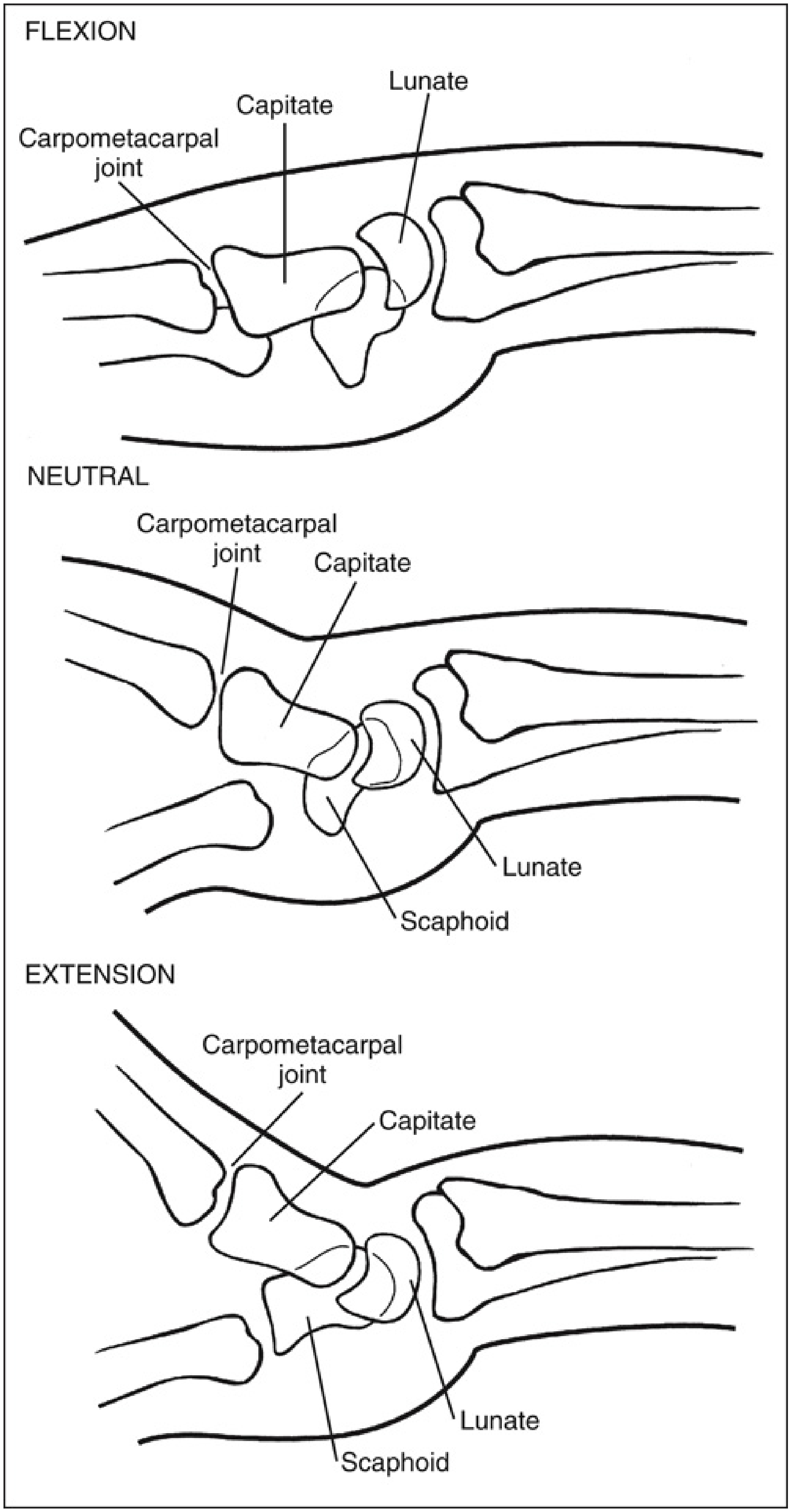

FLEXION
Lunate
Capitate
Carpometacarpal
joint
NEUTRAL
Carpometacarpal
joint
Capitate
Lunate
Scaphoid
EXTENSION
Carpometacarpal
joint
Capitate
Lunate
Scaphoid

FIGURE 4.74 Lateral wrist in flexion *(top)*, neutral position *(middle)*, and extension *(bottom)*.

Wrist Deviation

If the long axes of the third MC and the midforearm are aligned, positioning the midpoint of the lunate distal to the radioulnar articulation, the wrist has been placed in a neutral position, without radial or ulnar deviation. **Fig. 4.78** illustrates how wrist deviation alters the shape of the scaphoid and the position of the lunate with respect to the radioulnar articulation.

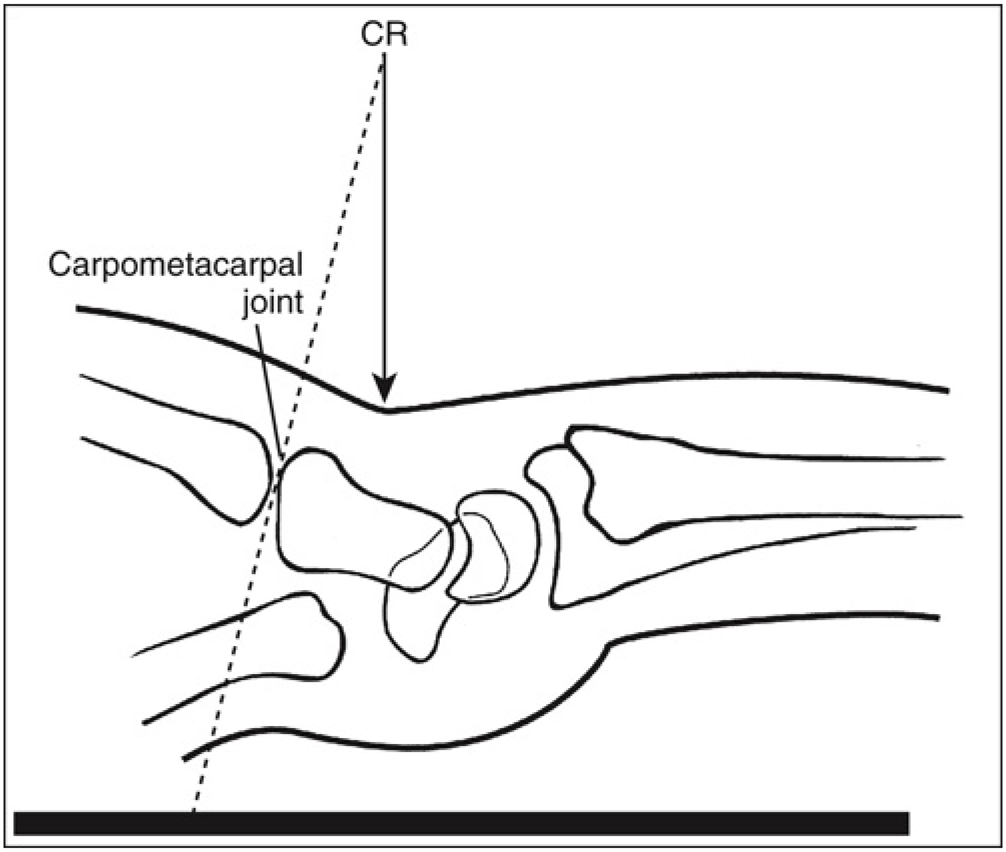


FIGURE 4.75 When the wrist is placed in a neutral position by accurate MC angulation with the IR for a PA wrist projection, the second through fifth CM joints will be open.

4.79).

FIGURE 4.76 PA wrist projection taken with the second MC placed at a 10-degree angle with the IR and the fifth MC positioned at less than a 15-degree angle with the IR.

Radial Deviation

Radial deviation of the wrist results in the third MC pointing toward the medial side of the wrist and it situates the lunate medially so it is more distal to the ulna and demonstrates increased scaphoid foreshortening (**Fig. 4.79**).

FIGURE 4.77 PA wrist projection taken with the fifth MC placed at a 15-degree angle with the IR and the second MC at greater than a 15-degree angle with the IR.

Ulnar Deviation

Ulnar deviation of the wrist results in the third MC pointing toward the lateral side of the wrist and it situates the lunate laterally so it is more distal to the radius (**Fig. 4.80**).

Demonstrating Wrist Joint Mobility

Radial and ulnar deviated wrist projections may be specifically requested to demonstrate wrist joint mobility. If this is the case, two PA projections are obtained, one with the wrist in radial deviation and one with the wrist in ulnar deviation. The radial deviated wrist should demonstrate a foreshortened scaphoid that forms a signet ring configuration and the center of the lunate more distal to the ulna (see Figs. **4.78** and **4.79**). The ulnar deviated wrist demonstrates decreased scaphoid foreshortening and the center of the lunate more distal to the radius (see **Fig. 4.80**).

First MC Positioning

Failure to abduct the thumb away from the second MC will result in a projection that demonstrates the second MC superimposing the first MC (**Fig. 4.81**).

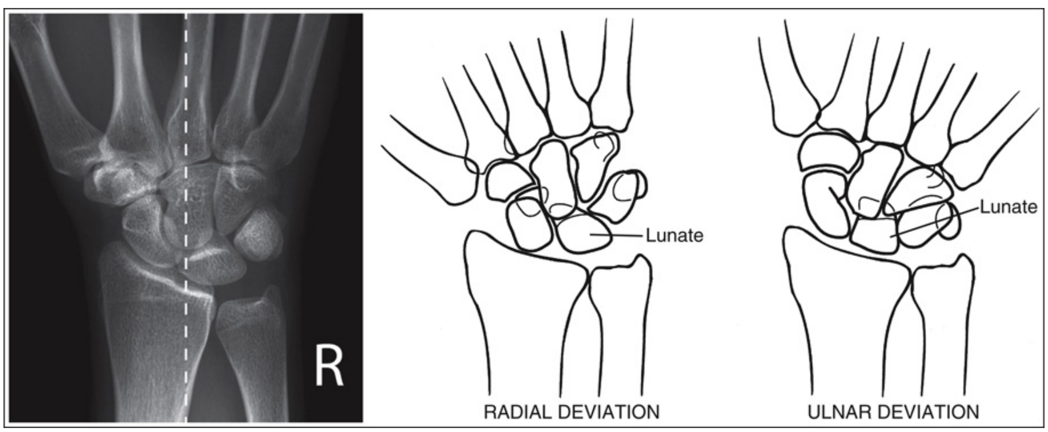


FIGURE 4.78 PA wrist projection in a neutral position and illustrations of radial deviation *(left)* and ulnar deviation *(right)*.

FIGURE 4.79 PA wrist projection taken with the wrist in radial deviation.

FIGURE 4.80 PA wrist projection taken with the wrist in ulnar deviation.

FIGURE 4.81 PA wrist projection obtained without the thumb being abducted from beneath the second MC.

PA Wrist Image Analysis Practice

IMAGE 4.16

Analysis

The third MC is not aligned with the long axis of the midforearm, and the second through third CM joints are closed. The wrist was in radial deviation and the second and third MCs were at a greater than 10- to 15-degree angle with the IR.

Correction

Ulnar deviate the wrist until the third MC is aligned with the long axis of the midforearm, and decrease the second and third MC's angle with the IR.

IMAGE 4.17

Analysis

The medially located carpals and proximal MCs are superimposed, and the radioulnar articulation is closed. The wrist was in external rotation for this projection. The posterior radial margin superimposes more than one-fourth of the lunate. The forearm was not parallel.

Correction

Rotate the wrist internally until it is in a PA projection and depress the proximal forearm until the forearm is parallel with the IR.

IMAGE 4.18

Analysis

The third MC is not aligned with the long axis of the midforearm. The wrist was in ulnar deviation. The second and third CM joints are closed. The second and third MCs were at a greater than 10- to 15-degree angle with the IR.

Correction

Radial deviate the wrist until the third MC is aligned with the long axis of the midforearm, and decrease the second and third MC's angle with the IR

to 10 degrees with the IR while maintaining the MC angles of the fourth and fifth MC.

Wrist: PA Oblique Projection (External Rotation)

See **Table 4.12** and Figs. **4.82** and **4.83**.

Radial Deviation

Radial deviation of the wrist results in the third MC pointing toward the medial side of the wrist and it moves the lunate medially, so more than half of the lunate is distal to the ulna (**Fig. 4.84**).

Ulnar Deviation

Ulnar deviation of the wrist results in the third MC pointing toward the lateral side of the wrist and it moves the lunate laterally, so less than half of the lunate is distal to the ulna (**Fig. 4.85**).

TABLE 4.12

CR, Central ray; *IR*, image receptor; *PA*, posteroanterior.

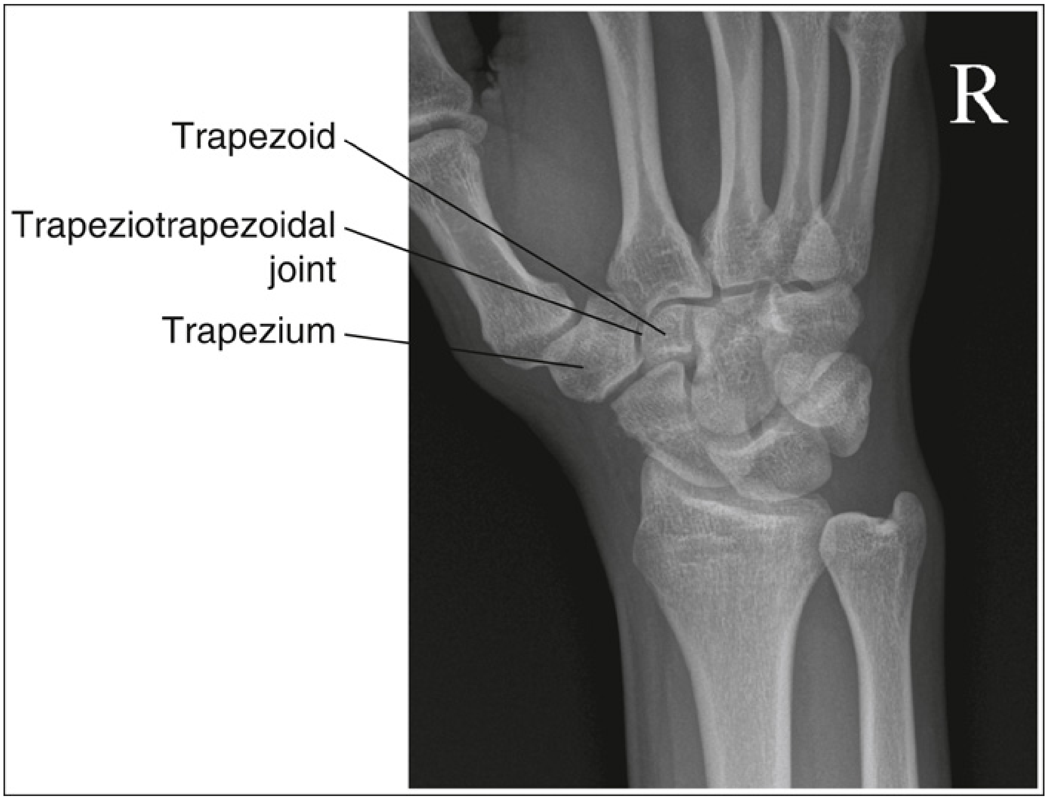


FIGURE 4.82 PA oblique wrist projection with accurate positioning.

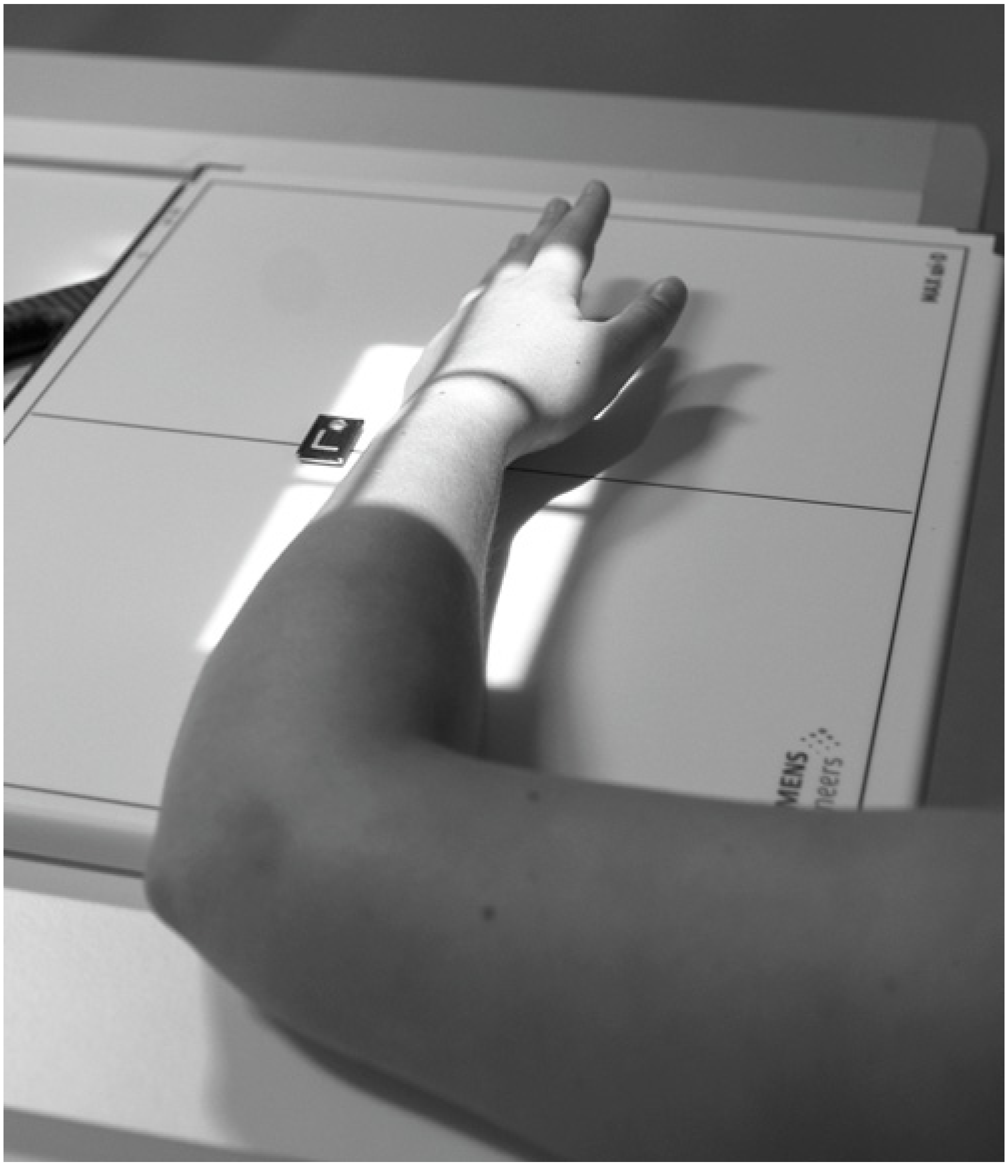


FIGURE 4.83 Proper patient positioning for PA oblique wrist projection.

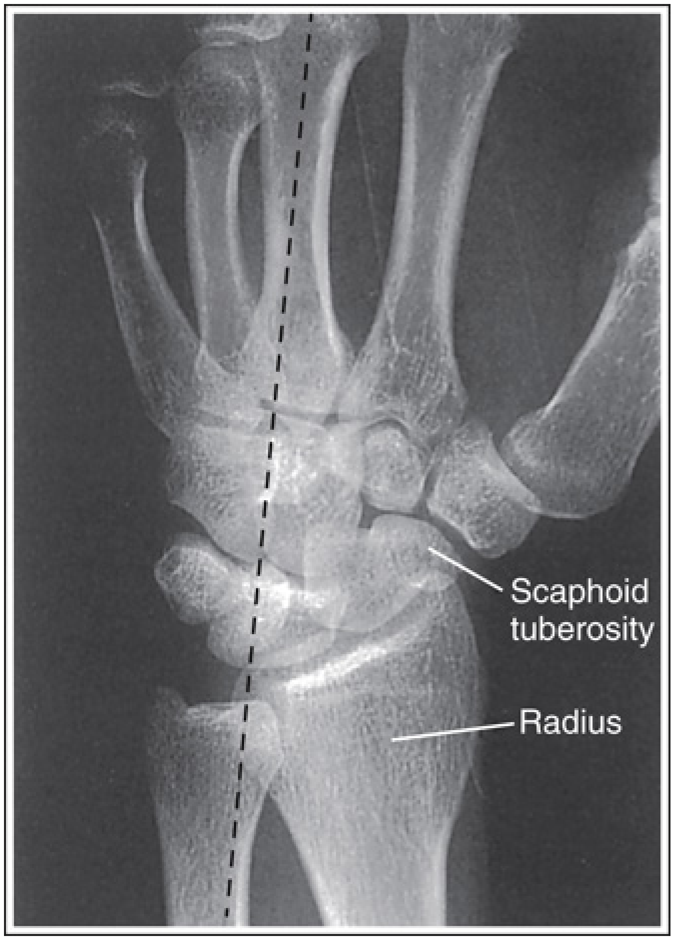


FIGURE 4.84 PA oblique wrist taken with the wrist in radial deviation.

FIGURE 4.85 PA oblique wrist taken with the wrist in ulnar deviation.

Wrist Extension: Elevated Proximal Forearm

If the proximal forearm is elevated higher than the distal forearm on a PA oblique wrist projection, the wrist is extended and the resulting projection demonstrates the posterior radial margin superimposing more than one-fourth of the lunate (Figs. **4.86** and **4.87B**).

Wrist Flexion: Depressed Proximal Forearm

If the proximal forearm is depressed lower than the distal forearm, the wrist is flexed and the posterior radial margin will superimpose less than one-fourth of the lunate. With enough proximal forearm depression the anterior and posterior radial margins will superimpose, demonstrating open radioscaphoid and radiolunate joint spaces (see Figs. **4.73**, **4.87A**, and **4.88**). Positioning to purposely open these joints may be beneficial when a distal forearm fracture is suspected.

FIGURE 4.86 PA oblique projection taken with the proximal forearm elevated and with less than 45 degrees of wrist obliquity.

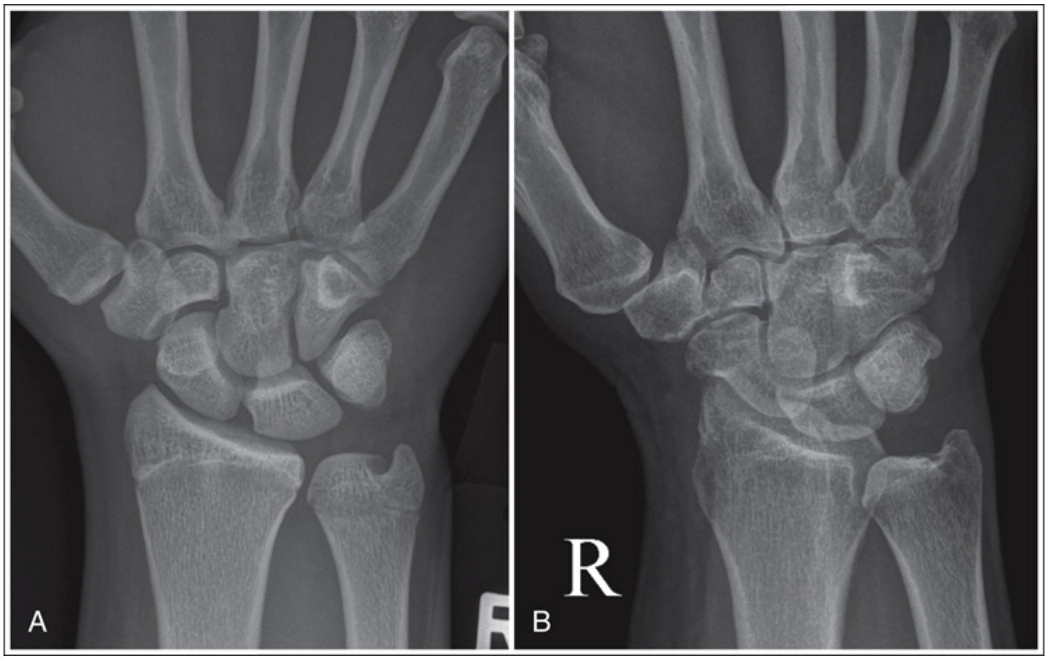


FIGURE 4.87 PA oblique wrist projections obtained with less than 45 degrees of obliquity. The first projection is an AP projection (A), and the second projection demonstrates about 20 degrees of obliquity (B).

Hand Flexion and Extension

For the PA wrist projection, the second CM and the scaphotrapezial joint spaces are opened by flexing the hand until the second MC is placed at a 10-degree angle with the IR (and with the anterior plane of the wrist). This same hand flexion needs to occur on the PA oblique wrist to demonstrate an open second CM joint space, but because the MCs are not positioned adjacent to the IR for this projection, the 10-degree MC angle needs to be maintained with the anterior plane of the wrist.

FIGURE 4.88 PA oblique projection taken with wrist flexion caused by depression of the proximal forearm.

FIGURE 4.89 PA oblique wrist projection taken with wrist extension caused by excessive hand flexion.

Hand Over-Flexion (Wrist Extension)

If the second MC is positioned at a greater than 10-degree angle with the anterior wrist plane, the resulting projection will demonstrate the proximal second MC superimposing and obscuring the trapezoid (**Fig. 4.89**).

FIGURE 4.90 PA oblique wrist projection taken with more than 45 degrees of wrist obliquity and the ulnar styloid is not in profile (see **Fig. 4.67**).

Insufficient Wrist Obliquity

The trapezoid is shaped somewhat like a cone with the wide end posteriorly situated and the pointed end anteriorly situated. This means that the medial and lateral sides of the trapezoid are not parallel with each other. In a PA wrist projection, the trapeziocapitate joint is parallel with the CR and is demonstrated as an open space on the projection, while the

trapeziotrapezoidal joint space is closed due to the trapezoid superimposing about half of the trapezium (see **Fig. 4.87**). It takes 45 degrees of medial wrist obliquity to rotate the trapezoid off the trapezium, and bring the trapeziotrapezoidal joint space parallel with the CR and demonstrate it as an open space on the projection. This degree of obliquity causes the trapeziocapitate joint to close as the trapezoid superimposes a small part of the capitate.

If wrist obliquity is less than the required 45 degrees for an oblique wrist, the trapeziocapitate joint is open if it is PA and will start to close with increased external rotation, the posterior trapezoid superimposes about half of the trapezium, closing the trapeziotrapezoidal joint space, and the third through fourth or fifth MC midshafts are superimposed (see **Fig. 4.87**).

Excessive Wrist Obliquity

If wrist obliquity is more than the required 45 degrees the trapeziotrapezoidal and the trapeziocapitate joint spaces are closed, the trapezium superimposes a small part of the anterior aspect of the trapezoid, one-half or more of the trapezoid superimposes the capitate, and the third or fourth through fifth MC midshafts are superimposed (**Fig. 4.90**).

PA Oblique Wrist Analysis Practice

IMAGE 4.19

Analysis

The trapeziotrapezoidal and the trapeziocapitate joint spaces are closed, the trapezium superimposes a small part of the trapezoid, one-half of the trapezoid superimposes the capitate, and the fourth and fifth MC midshafts are superimposed. The wrist was rotated more than 45 degrees medially. The posterior radial margin superimposes more than one-fourth of the lunate. The proximal forearm was elevated. The ulnar styloid is not in profile.

Correction

Decrease medial wrist obliquity to 45 degrees, depress the proximal forearm to bring it parallel with IR, and position the humeral epicondyles perpendicular to the IR.

IMAGE 4.20

Analysis

The second MC is superimposing the trapezoid, the posterior radial margin is superimposing more than one-fourth of the lunate, and

trapeziotrapezoidal joint space is closed. The second MC was flexed more than 10 degrees with the anterior plane of the wrist, the proximal forearm was elevated, and the wrist was rotated more than 45 degrees.

Correction

Decrease the degree of hand flexion until the second MC is at a 10-degree angle with the anterior wrist plane, depress the proximal forearm to bring it parallel with IR, and decrease the amount of external rotation.

IMAGE 4.21

Analysis

The trapeziotrapezoidal and trapeziocapitate joint spaces are closed, the trapezoid superimposes up to one-half of the trapezium, and less than one-half of the trapezoid superimposes the capitate. The wrist was slightly underrotated. The third MC is pointing laterally and the lunate is distal to the radius, and the posterior radial margin superimposes more than one-fourth of the lunate. The third MC was not aligned with the midforearm, and the proximal forearm was elevated.

Correction

Increase medial wrist obliquity to 45 degrees, align the long axis of the third MC and the midforearm, and depress the proximal forearm to bring it parallel with IR.

Wrist: Lateral Projection (Lateromedial)

See **Table 4.13** and Figs. **4.91** and **4.92**.

Alternate Humerus Positioning

In contrast to positioning the forearm and humerus on the same horizontal plane with the humeral epicondyles placed parallel with the IR, a lateral wrist projection may be taken with zero forearm rotation. For this to be accomplished the humerus is not abducted but extended with the elbow placed in an AP projection, aligning the humeral epicondyles parallel with the IR (**Fig. 4.93**). Such positioning rotates the ulnar styloid out of profile, demonstrating it distal to the midline of the ulnar head (see **Fig. 4.67**). Because forearm rotation has been eliminated, the ulnar head also shifts closer to the lunate. This positioning allows for more accurate measuring of

the ulnar length. Department policy determines which humerus positioning is performed in your facility.

TABLE 4.13

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

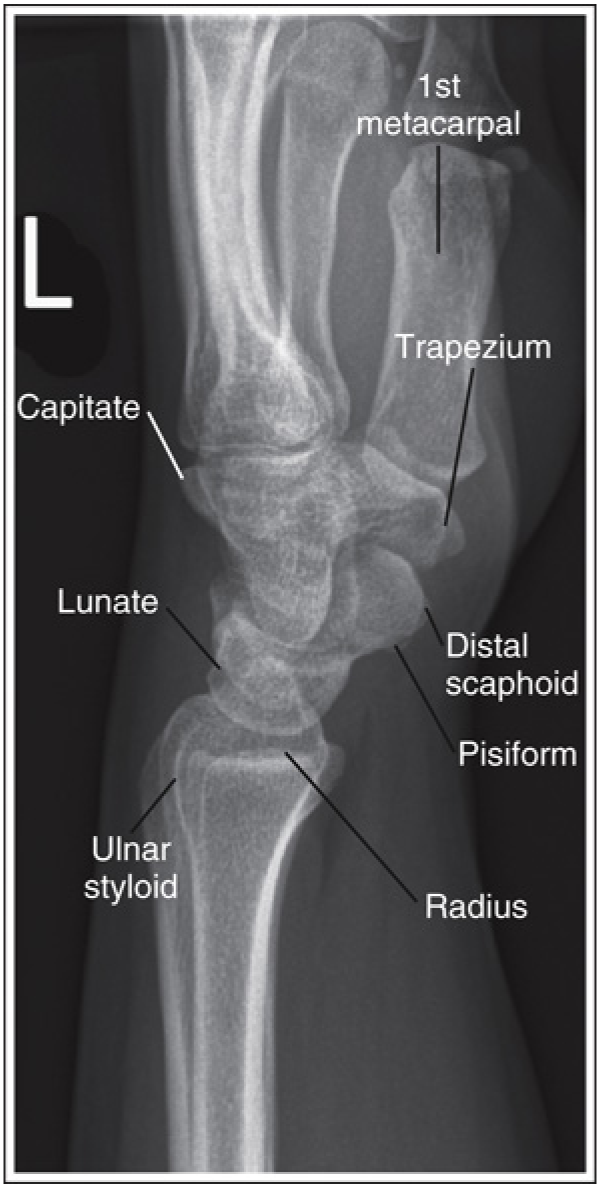


FIGURE 4.91 Lateral wrist projection with accurate positioning.

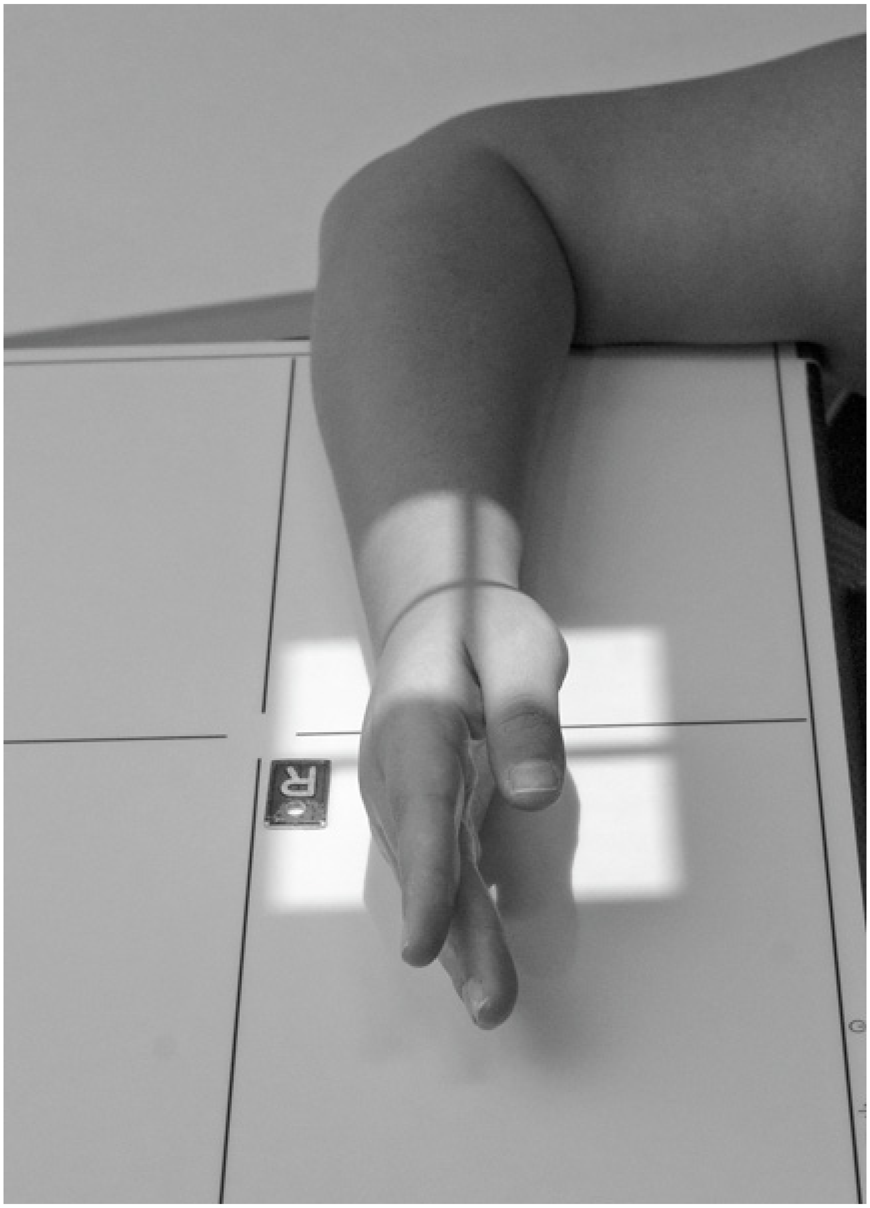


FIGURE 4.92 Lateral wrist projection with humeral abduction and the humeral epicondyles aligned perpendicular with the IR.

Pronator Fat Stripe

The pronator fat stripe is one of the soft tissue structures that are demonstrated on lateral wrist projections (**Fig. 4.94**). It is located parallel to

the anterior surface of the distal radius, is normally convex, and lies within 0.25 inch (0.6 cm) of the radial cortex. Bowing or obliteration of this fat stripe may be the only indication of a subtle radial fracture. Failure to obtain a true lateral projection will obscure this stripe.

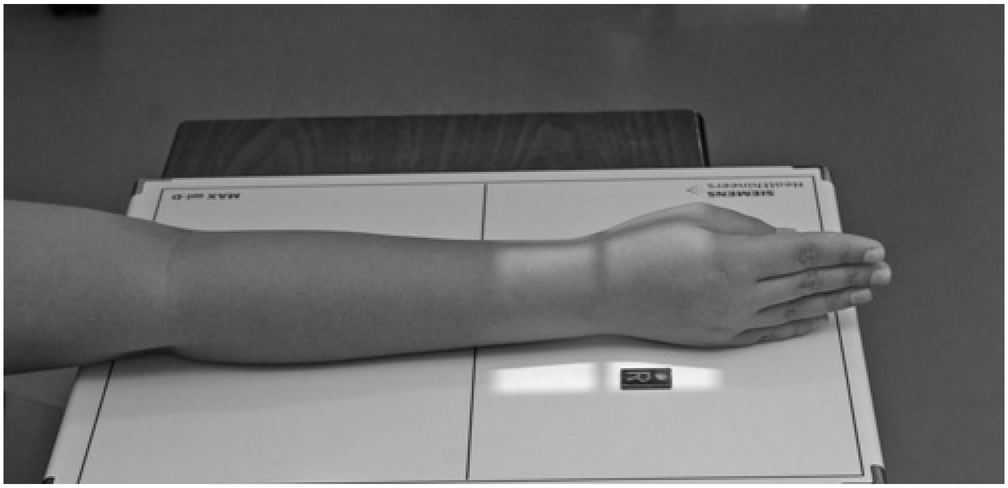


FIGURE 4.93 Lateral wrist projection with the humerus extended and the humeral epicondyles aligned parallel with IR.

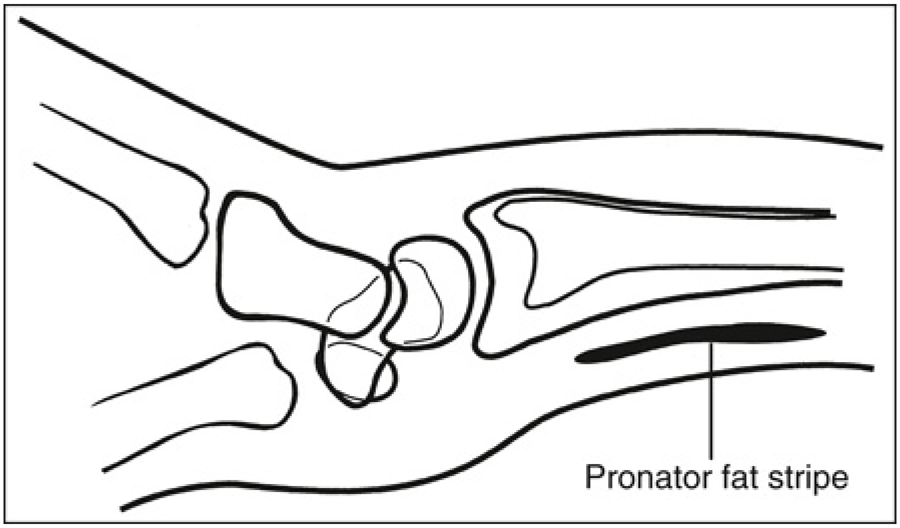


FIGURE 4.94 Location of pronator fat stripe on a lateral wrist projection.

Distal Scaphoid and Pisiform Alignment

The relationship between the pisiform and distal aspect of the scaphoid can best be used to discern whether a lateral wrist projection has been obtained without rotation and without deviation. On a good lateral projection, the anterior and the proximal cortical margins of these two carpals are aligned as demonstrated in **Fig. 4.95**.

External Wrist Rotation

If the anterior aspect of the distal scaphoid is positioned posterior to the anterior aspect of the pisiform on a lateral wrist projection, the wrist was externally rotated (**Fig. 4.96**).

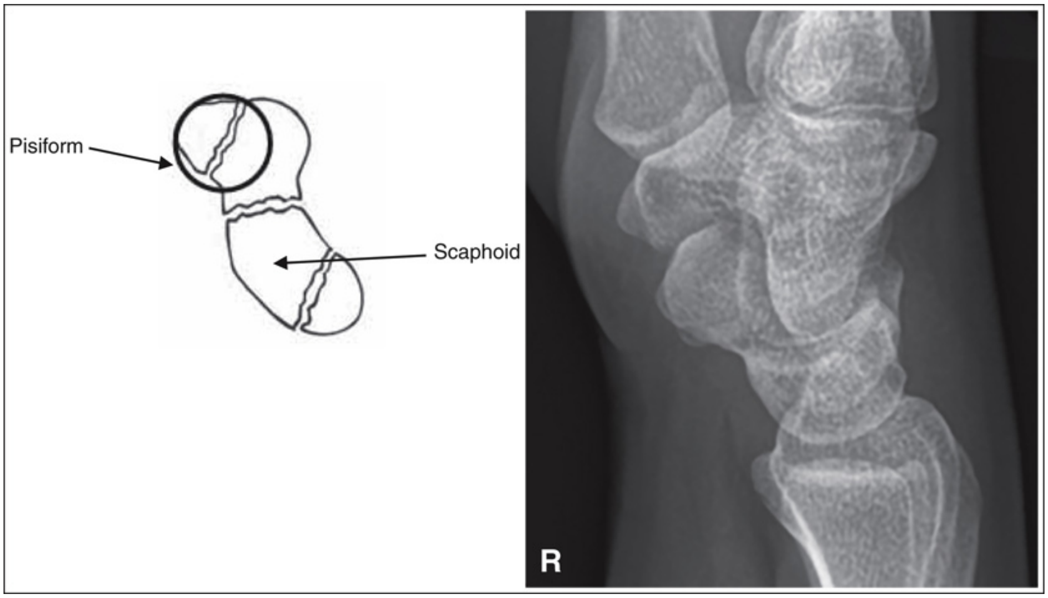
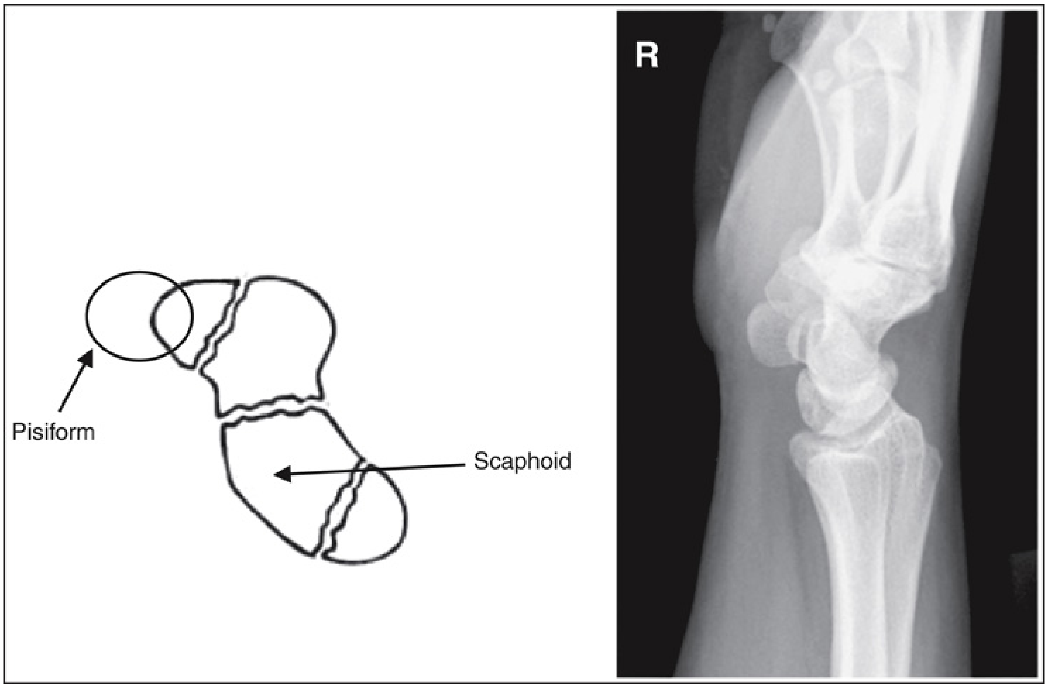


FIGURE 4.95 Distal scaphoid and pisiform are aligned anteriorly and distally on an accurately positioned lateral wrist projection.



Pisiform
Scaphoid
R

FIGURE 4.96 Lateral wrist projection taken with the wrist in external rotation. Pisiform is demonstrated anterior to the distal scaphoid.

Internal Wrist Rotation

If the anterior aspect of the distal scaphoid is positioned anterior to the anterior aspect of the pisiform on a lateral wrist projection, the wrist was internally rotated (Figs. **4.97** and **4.98**).

Distal Alignment of the Distal Scaphoid and Pisiform

If the third MC and midforearm are not aligned, the proximal forearm is positioned higher or lower than the distal forearm, causing the wrist to radial or ulnar deviate, respectively. With radial and ulnar deviation, the distal scaphoid moves but the pisiform's position remains relatively unchanged (**Fig. 4.99**).

Radial Deviation: Proximal Forearm Elevated

If the proximal forearm is elevated higher than the distal forearm, the wrist is radial deviated. Radial deviation of the wrist forces the distal scaphoid to move anteriorly and proximally, causing the distal aspect of the distal scaphoid to be positioned proximal to the distal aspect of the pisiform (**Fig. 4.100**).

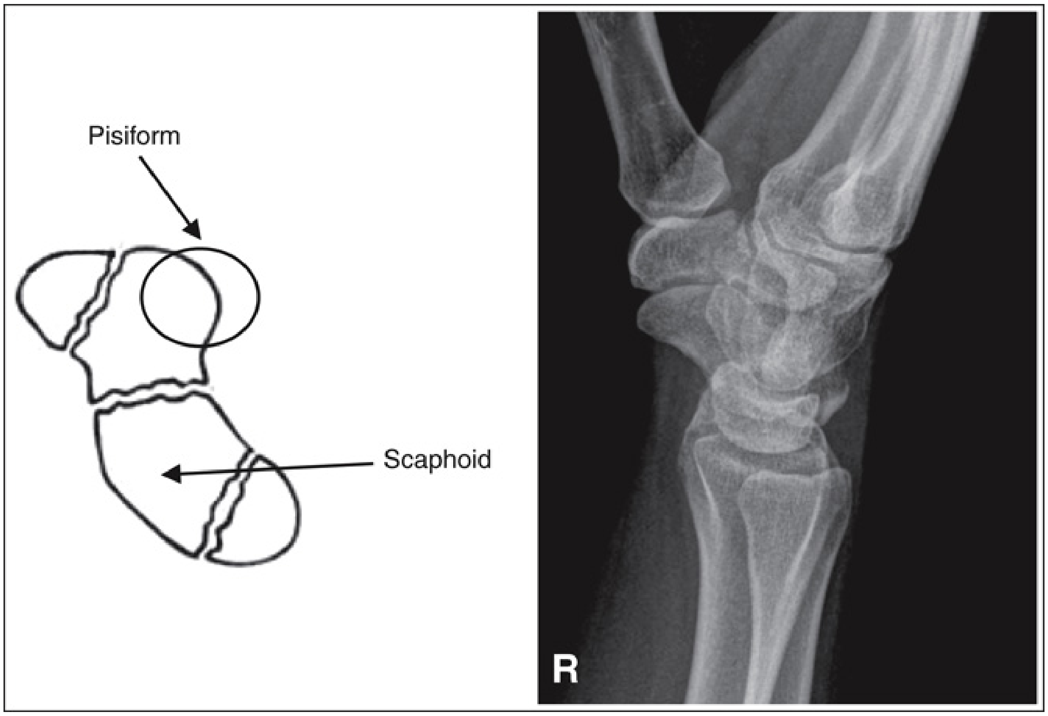


FIGURE 4.97 Lateral wrist projection taken with the wrist in internal rotation. Pisiform is seen posterior to the distal scaphoid.

Ulnar Deviation: Proximal Forearm Depressed

If the proximal forearm is depressed more than the distal forearm, the wrist is ulnar deviated. Ulnar deviation of the wrist shifts the distal scaphoid posteriorly and distally, causing the distal aspect of the distal scaphoid to be positioned distal to the distal aspect of the pisiform (**Fig. 4.101**).

FIGURE 4.98 Pediatric lateral wrist projection taken with the wrist in internal rotation.

Wrist Flexion

In wrist flexion the MCs are at a greater than 15-degree angle with the anterior wrist plane (**Fig. 4.102**).

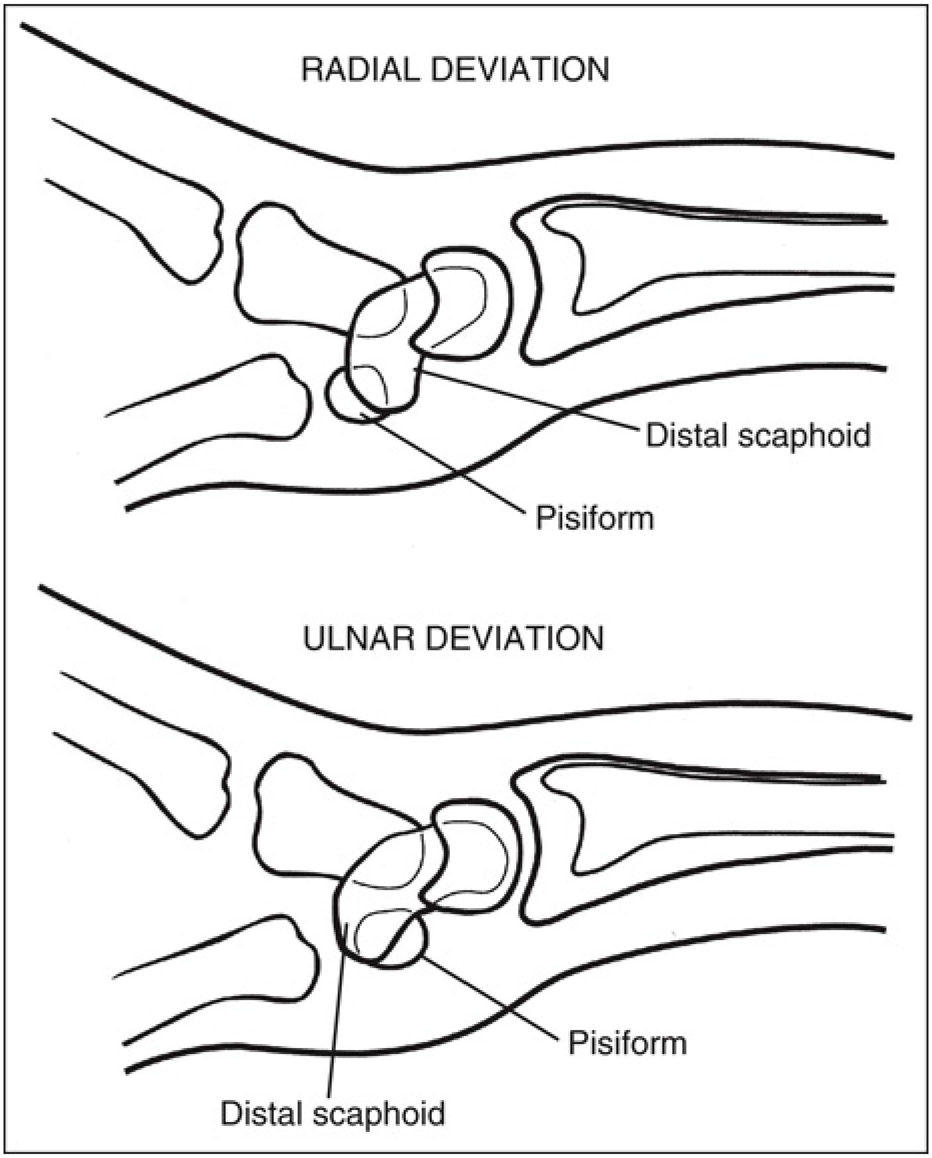


FIGURE 4.99 Lateral wrist in radial deviation *(top)* and ulnar deviation *(bottom)* to demonstrate the change in proximal/distal alignment of the pisiform and distal scaphoid.

Wrist Extension

In wrist extension the MCs are at a less than 10-degree angle with the anterior wrist plane (see **Fig. 4.102**).

Wrist Joint Mobility Procedure

Lateral flexion and extension projections of the wrist may be specifically requested to demonstrate wrist joint mobility. These projections are completed by positioning the patient in maximum allowable flexion and extension as demonstrated in **Fig. 4.103**.

Thumb Depression and Trapezium Visualization

If the first MC is not depressed, it is foreshortened, and its proximal aspect is superimposed over the trapezium (**Fig. 4.104**).

CR Centering

Centering the CR to the distal forearm in an attempt to include more than one-fourth of the distal forearm will result in the distal scaphoid being projected distal to the pisiform (**Fig. 4.105**). If it is necessary to obtain a projection that includes more of the forearm, the CR should remain on the wrist joint, and the collimation field opened to demonstrate the desired amount of forearm. This method results in an extended, unnecessary radiation field distal to the MCs that should not be included on the projection. A lead strip or apron placed over this extended radiation field will protect the hand and prevents backscatter from this area from reaching the IR.

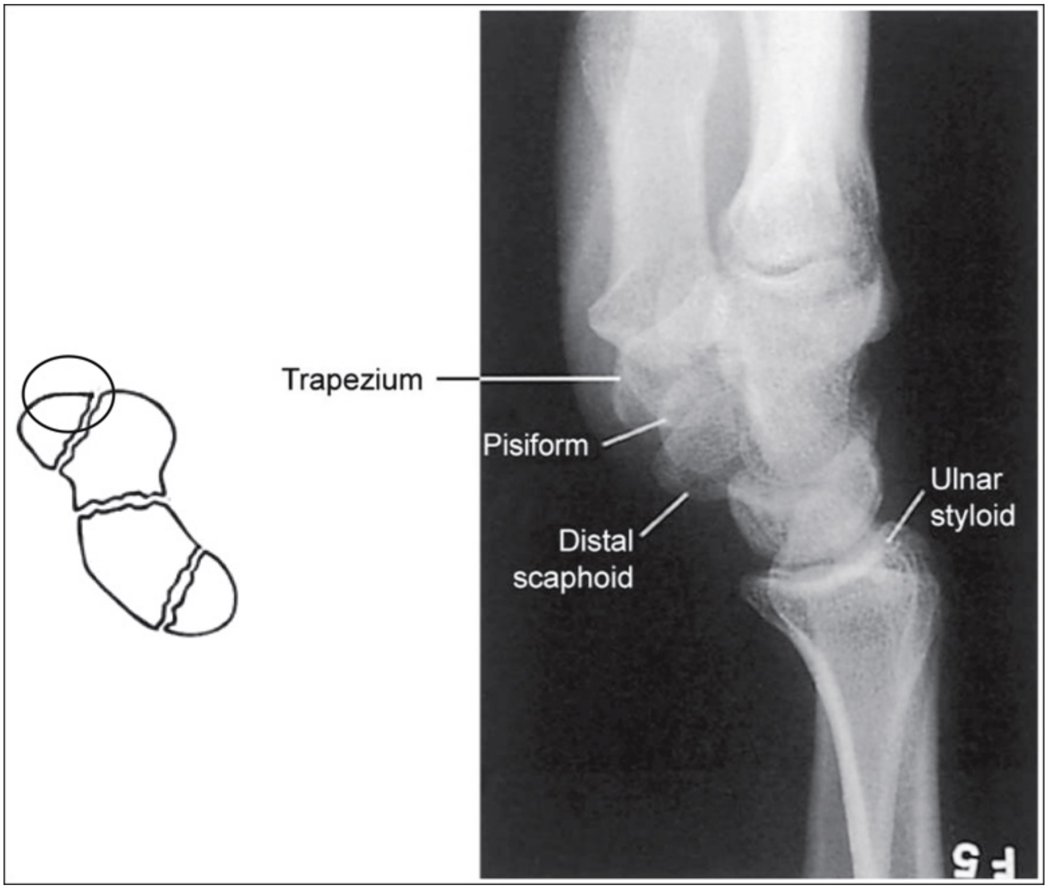


FIGURE 4.100 Lateral wrist projection taken with the wrist in radial deviation. Pisiform is seen distal to the distal scaphoid.

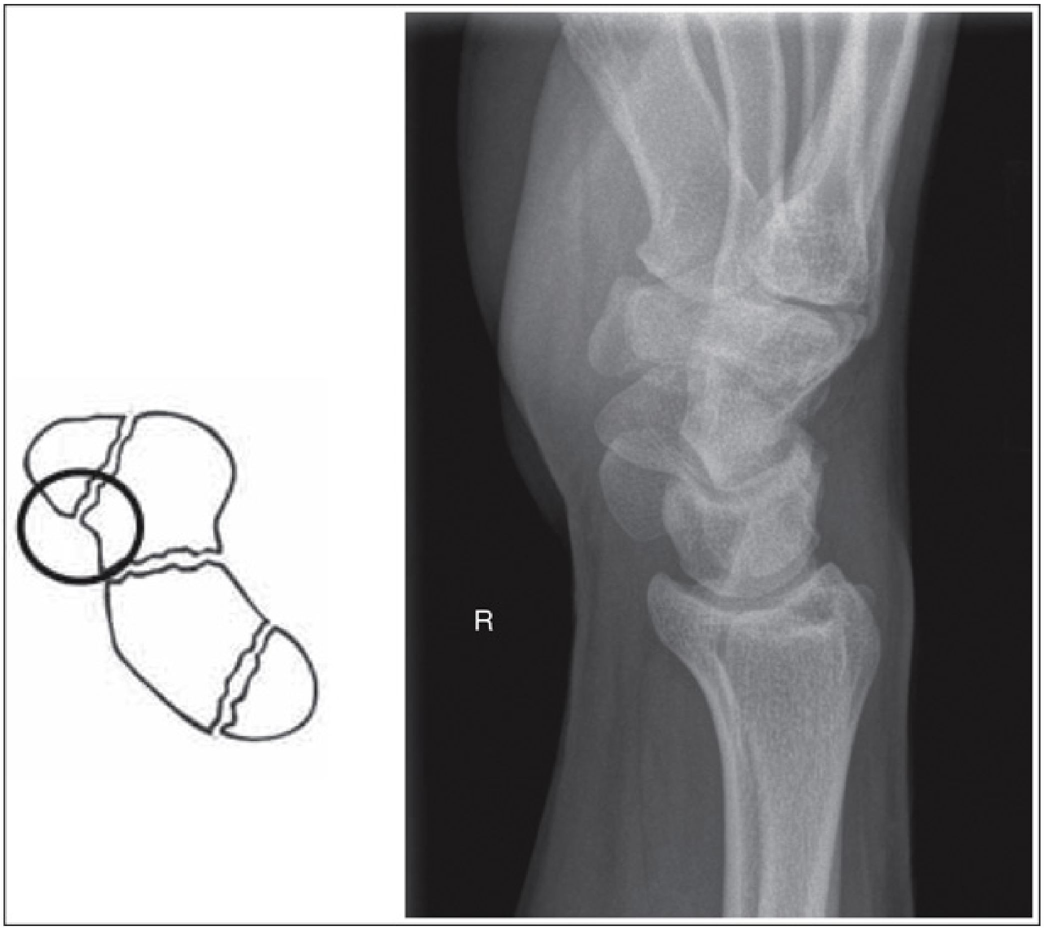


FIGURE 4.101 Lateral wrist projection with the wrist in ulnar deviation. Pisiform is demonstrated proximal to the distal scaphoid.

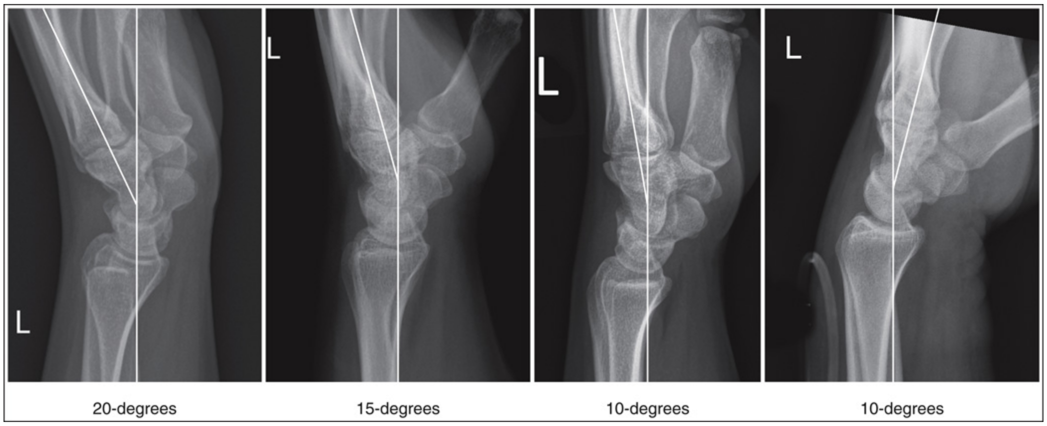


FIGURE 4.102 Lateral wrist projections demonstrating different degrees MC alignment with the anterior plane, causing wrist flexion and extension. The goal is 10 to 15 degrees posteriorly.

image

FIGURE 4.103 Lateral wrist projections. The first projection was taken with the wrist in flexion and the second was taken with the wrist in extension.

image

FIGURE 4.104 Lateral wrist projection taken without the thumb being positioned parallel with the IR.

FIGURE 4.105 Lateral wrist projection taken with CR positioned distal to the wrist to include more than one-fourth of the distal forearm, causing the pisiform to be proximal to the distal scaphoid.

Lateral Wrist Analysis Practice

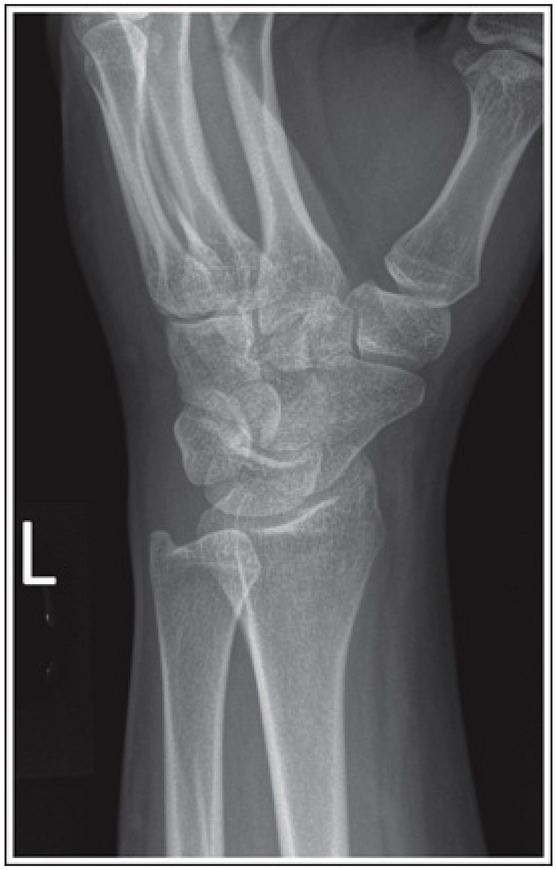


IMAGE 4.22

Analysis

The anterior aspect of the distal scaphoid is anterior to the anterior aspect of the pisiform and the radius is anterior to the ulna. The wrist was internally rotated.

Correction

Externally rotate the wrist until the wrist is in a lateral projection.

image

IMAGE 4.23

Analysis

The distal aspect of the distal scaphoid is demonstrated distal to the pisiform. The wrist was in ulnar deviation.

Correction

Place the wrist in a neutral position by elevating the proximal forearm until the long axis of the third MC and the midforearm are aligned parallel with the IR.

image

IMAGE 4.24

Analysis

The first proximal MC is superimposed over the trapezium. The thumb was not depressed and placed parallel with the IR.

Correction

Depress the thumb, placing it and the second MC at the same horizontal level and parallel with the IR.

image

IMAGE 4.25

Analysis

The anterior aspect of the pisiform is demonstrated anterior to the anterior aspect of the distal scaphoid. The wrist was externally rotated.

Correction

Internally rotate the wrist until the wrist is in a lateral projection.

Wrist: Ulnar Deviation, PA Axial Projection (Scaphoid)

See **Table 4.14** and Figs. **4.106** and **4.107**.

Open Scaphotrapezium and Scaphotrapezoidal Joint Spaces

The scaphotrapezium and scaphotrapezoidal joint spaces are aligned at a 15-degree angle to the IR when the hand is pronated and fully extended. On the PA axial projection, because the required 15-degree proximal (toward the elbow) CR angle aligns the x-ray beam with these joints they are demonstrated as open spaces. If the hand is not extended and the palm placed flat against the IR, but rather is flexed, the second MC is superimposed over the trapezoid and trapezium, closing the scaphotrapezium and scaphotrapezoidal joint spaces (**Fig. 4.108**).

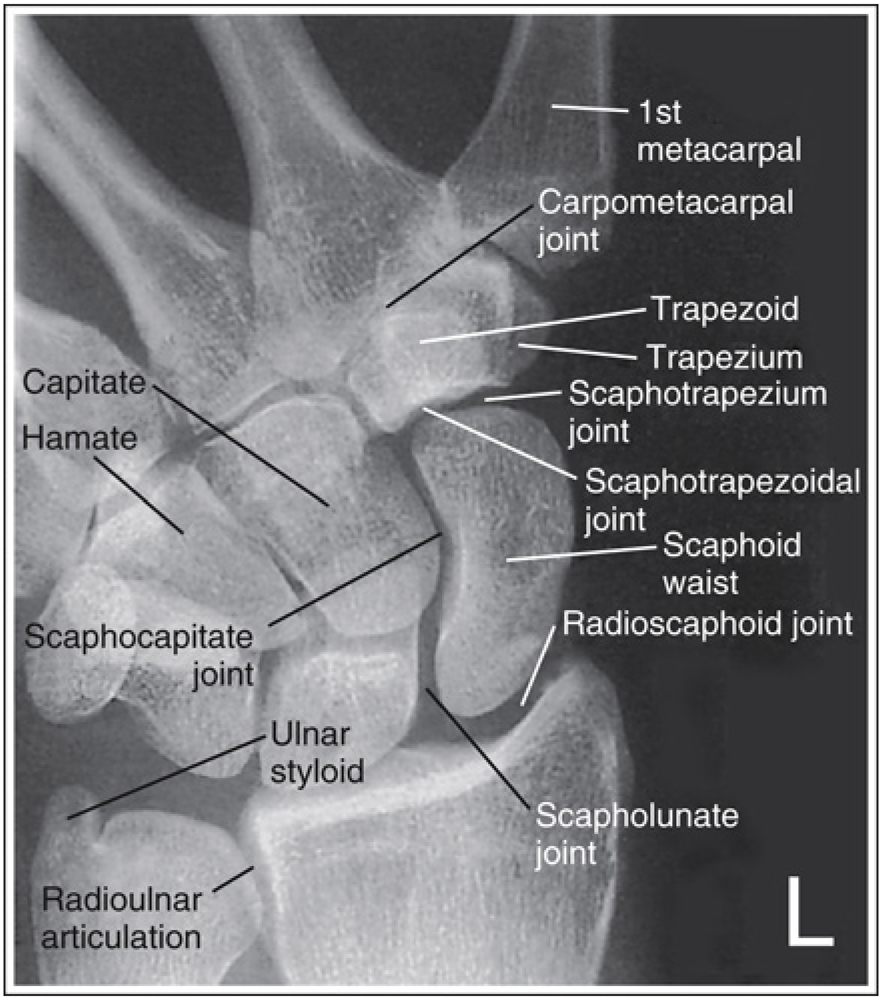


FIGURE 4.106 Ulnar-deviated, PA axial (scaphoid) wrist projection with accurate positioning.

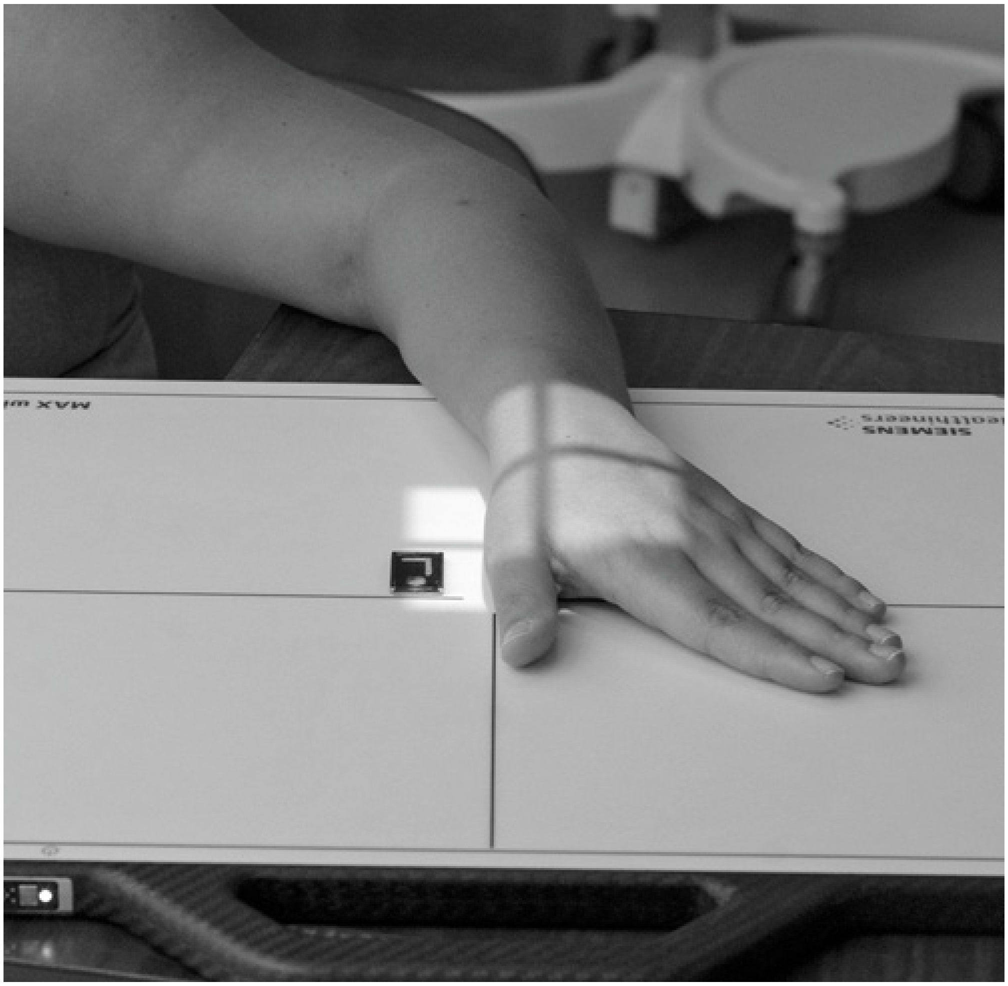


FIGURE 4.107 Proper patient positioning for the PA axial wrist projection.

TABLE 4.14

CR, Central ray; *IR*, image receptor; *PA*, posteroanterior.

Ulnar Deviation

In a neutral PA projection of the wrist, the distal scaphoid tilts anteriorly and the scaphoid's long axis is at approximately a 20-degree angle with the IR, causing foreshortening distortion of the scaphoid on the projection (**Fig. 4.109**). To offset some of this foreshortening and better demonstrate the

scaphoid, the wrist is placed in maximum ulnar deviation to reduce the distal scaphoid's anterior tilt to 15 degrees, and a 15-degree proximal CR angulation is directed to the long axis of the scaphoid for a PA axial scaphoid projection (see **Fig. 4.109**). Maximum ulnar deviation has been accomplished when the first MC is aligned with the radius. When maximum ulnar deviation and the 15-degree proximal CR angle are used, the CR is aligned perpendicular to the scaphoid waist, which is where 70% of all scaphoid fractures occur (see **Fig. 4.109**).

image

FIGURE 4.108 PA axial wrist projection demonstrating a scaphoid waist fracture, taken without the hand extended and palm placed flat against the IR and the wrist in maximum ulnar deviation.

Many patients with suspected scaphoid fractures are unable to achieve maximum ulnar wrist deviation. This places the scaphoid's long axis at a greater than 15-degree angle with the CR and results in the projection demonstrating increased scaphoid foreshortening unless the CR angulation is increased to a 20-degree proximal angle to compensate (**Fig. 4.110**). Because the CR and IR angle is more acute with this setup, the resulting projection will demonstrate increased elongation compared to the patient that can achieve maximum ulnar wrist deviation.

Insufficient Wrist Obliquity: Scaphocapitate Joint Space

When the humerus is abducted and positioned parallel with the IR, and the elbow placed in a flexed lateral projection, as the wrist is ulnar deviated it often will naturally externally rotate about 25 degrees, opening the

scaphocapitate and scapholunate joint spaces. If the wrist does not naturally rotate to 25 degrees when the patient ulnar deviates or if the patient is unable to reach maximum ulnar deviation, increase the degree of medial wrist rotation as needed to obtain 25 degrees. Insufficient wrist obliquity demonstrates open scapholunate and hamate-capitate joint spaces, and a closed scaphocapitate joint (**Fig. 4.111**).

image

FIGURE 4.109 Illustration of lateral wrist in neutral position *(left top)* and in ulnar deviation *(left bottom)* to show the changes in the alignment of the long axis of the scaphoid with the IR when the wrist is ulnar deviated. The illustration on the right demonstrates accurate alignment of the CR and scaphoid's longitudinal axis *(right)* for a PA axial wrist projection.

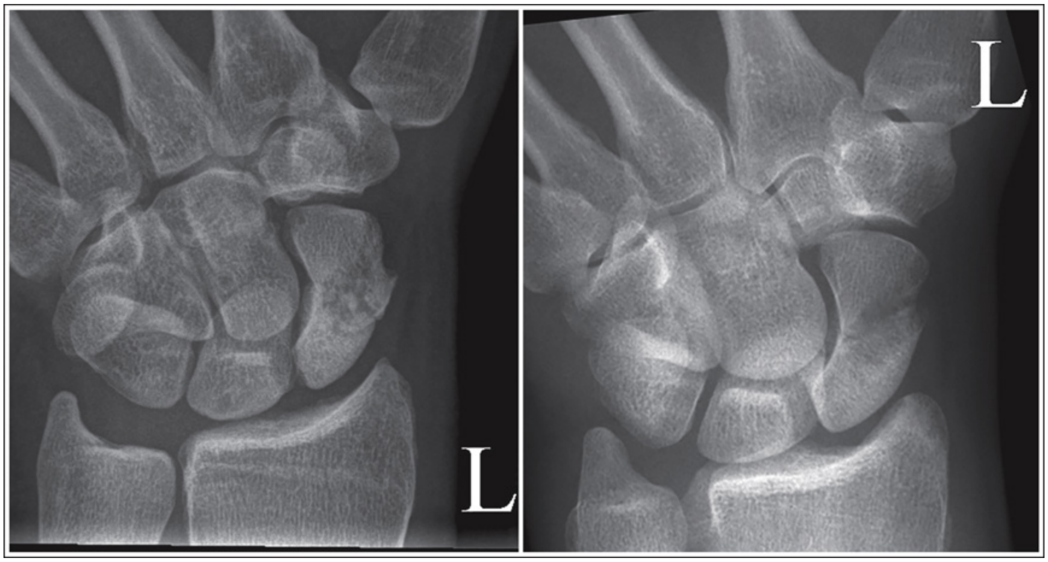


FIGURE 4.110 PA axial wrist projection demonstrating waist fractures of the scaphoid. The first projection shows slightly more ulnar flexion and external wrist rotation than the second projection.

Excessive Wrist Obliquity: Scapholunate Joint Space

If the wrist is externally rotated slightly more than needed for the PA axial projection, the scapholunate joint space is closed, the scaphocapitate joint space is open with slightly too much obliquity and closes with increased rotation, and the capitate and hamate demonstrate some degree of superimposition (**Fig. 4.112**). Excessive external wrist obliquity often occurs when the humerus and forearm are not positioned on the same horizontal plane for the projection.

Forearm: Radioscaphoid Joint Space

The distal radial carpal articular surface is concave and slants approximately 11 degrees from posterior to anterior when the forearm is positioned parallel with the IR. That is why the posterior radial margin

superimposes one-fourth of the lunate on a PA wrist projection when a perpendicular CR is used. With the 15-degree proximal CR angulation that is used for the PA axial projection, the posterior radial margin is projected proximally as illustrated in **Fig. 4.113** and is seen proximal to the anterior radial margin on the projection (**Fig. 4.114**). To demonstrate an open radioscaphoid joint, the anterior and posterior margins of the distal radius need to be superimposed. This superimposition is accomplished by elevating the proximal forearm very slightly above the distal forearm.

image

FIGURE 4.111 PA axial wrist projection with maximum ulnar deviation and inadequate medial wrist rotation.

CR Angulation: Alignment With Scaphoid Fractures

Three areas of the scaphoid may be fractured: the waist, which sustains approximately 70% of the fractures; the distal end, which sustains 20% of the fractures; and the proximal end, which sustains 10% (**Fig. 4.115**). The scaphoid is the most commonly fractured carpal bone. One reason for this is its location among the other carpal bones. The wrist has two rows of carpals, a distal row and a proximal row, with joint spaces between them that allow the wrist to move. The scaphoid bone, however, is aligned partially with both of these rows, with no joint space. When an individual falls on an outstretched hand, the wrist is hyperextended, causing the proximal and distal carpal rows to flex at the joints, and a great deal of stress to be placed on the narrow waist of the scaphoid. This stress often results in a fracture at the scaphoid waist. Because scaphoid fractures of the

waist are the most common, the routine PA axial projection is initially set for the CR to align parallel with fractures in this area.

image

FIGURE 4.112 PA axial wrist projections taken with the wrist externally rotated more than needed. The first projection demonstrates less rotation than the second.

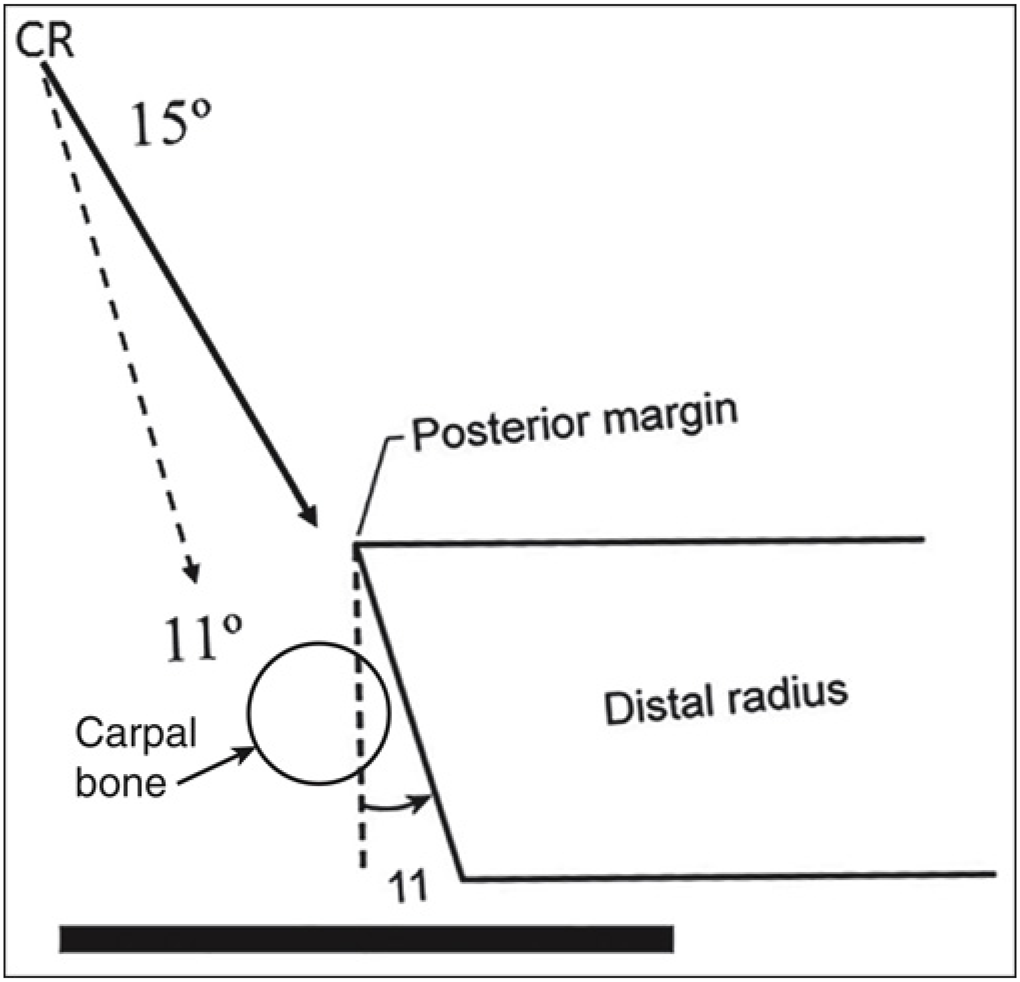


FIGURE 4.113 Alignment of the CR and distal radius for a PA axial wrist projection to demonstrate an open radioscaphoid joint.

image

FIGURE 4.114 PA axial wrist projection taken with proximal forearm elevated slightly above the distal forearm.

When a distal or a proximal scaphoid fracture is suspected it is necessary to vary the CR angulation from that used for the waist fracture to bring the

CR parallel with the fracture in these locations (**Fig. 4.116**).

CR Angulation: Proximal Scaphoid Fracture

A decrease of 5 to 10 degrees in CR angulation best demonstrates proximal scaphoid fractures. Compare Figs. **4.117** and **4.118**. These figures demonstrate PA axial projections that were obtained on the same patient that has a proximal scaphoid fracture. **Fig. 4.117** was taken with the typical 15-degree proximal angle, and **Fig. 4.118** was taken with a 5-degree proximal angle. Note the increase in fracture line visualization in **Fig. 4.118**.

image

FIGURE 4.115 Scaphoid fracture sites.

image

FIGURE 4.116 Adjusting the CR to best demonstrate distal, waist, and proximal scaphoid fractures on PA axial wrist projections.

CR Angulation: Distal Scaphoid Fracture

An increase of 5 to 10 degrees in CR angulation, with a maximum of 25 degrees, best demonstrates distal scaphoid fractures (**Fig. 4.119**). Angulations of more than 25 degrees project the proximal first MC onto the distal scaphoid, obscuring the area of interest (**Fig. 4.120**).

image

FIGURE 4.117 PA axial wrist projection taken with a 15-degree proximal CR angle demonstrating a proximal scaphoid fracture.

image

FIGURE 4.118 PA axial wrist projection taken with a 5-degree proximal CR angle demonstrating a proximal scaphoid fracture.

image

FIGURE 4.119 PA axial wrist projection taken with a 25-degree proximal CR angle and demonstrating a distal scaphoid fracture.

image

FIGURE 4.120 PA axial wrist projection taken with a 30-degree proximal CR angle. A distal scaphoid fracture is present, but not well demonstrated because the excessive CR angulation caused the second MC to superimpose the distal scaphoid.

PA Axial (Scaphoid) Analysis Practice

image

IMAGE 4.26

Analysis

The scaphotrapezium and scaphotrapezoidal joint spaces are closed. The hand was flexed. The scaphocapitate and scapholunate joint spaces are closed. The wrist was not adequately ulnar deviated, preventing external wrist rotation. The radioscaphoid joint space is closed. The proximal forearm was positioned slightly lower than the distal forearm.

Correction

Extend the hand, placing the palmar surface flat against the IR. Ulnar deviate the wrist until the long axis of the first MC and the radius are aligned or if patient is unable to deviate externally rotate the wrist to a 25-degree angle with the IR. Move the proximal forearm off the IR as needed to position the proximal forearm slightly higher (2 degrees) than the distal forearm.

image

IMAGE 4.27

Analysis

The scaphotrapezium and scaphotrapezoidal joint spaces are closed. The hand was not extended and the palm placed flat against the IR. The scaphocapitate joint is closed and the scapholunate joint is open. The wrist was not externally rotated enough. The radioscaphoid joint is closed. The proximal forearm was depressed.

Correction

Extend the hand and place the palm flat against the IR, medially rotate the wrist until wrist is at a 25-degree medial oblique, and elevate the proximal forearm until it is slightly higher than the distal forearm.

image

IMAGE 4.28

Analysis

The scaphotrapezoidal joint space is closed, the scaphocapitate and scapholunate joint spaces are closed, and the capitate and hamate demonstrate some degree of superimposition. The hand was not extended and the palm placed flat against the IR, and the wrist was externally rotated more than needed.

Correction

Extend hand and place the palm flat against the IR and slightly decrease the degree of external wrist rotation.

Wrist: Carpal Canal (Tunnel) (Tangential, Inferosuperior Projection)

See **Table 4.15** and Figs. **4.121** and **4.122**.

Carpal Canal Exam Indication

The carpal canal position is used to evaluate the carpal canal for the narrowing that results in carpal canal syndrome and demonstrate fractures of the pisiform and hamulus of the hamate. The carpal canal is a

passageway formed anteriorly by the flexor retinaculum, posteriorly by the capitate, laterally by the scaphoid and trapezium, and medially by the pisiform and hamate (**Fig. 4.123**).

CR Angulation: Adjusting for Patient's Ability to Hyperextend Wrist

Due to the different hand and wrist conditions that will cause variations in the degree of wrist hyperextension a patient can obtain, the CR angulation will need to be adjusted to remain at the needed 15 degrees with the MCs to demonstrate the carpal canal. Bringing the MCs as close to perpendicular to the IR as the patient allows is best as it will reduce the angle between the CR and IR, decreasing elongation of the structures.

To determine the degree of CR angulation to use for all the MC and IR angles that are possible, after the patient has hyperextended the wrist, align the CR so that it is parallel with the palmar surface, and then increase the angle an additional 15 degrees proximally (**Fig. 4.124**). The resulting projection demonstrates adequate visualization of the carpal bones and carpal canal, although there will be increased elongation as the angle between the CR and IR becomes more acute (**Fig. 4.125**).

Excessive CR Angulation

If the angle between the CR and MCs is greater than the required 15 degrees, the carpal canal will not be fully demonstrated and the carpal bones will be projected into the wrist and foreshortened (**Fig. 4.126**). This is especially noticed on the hamulus. As the CR is increased the pisotriquetral articulation demonstrates some degree of openness to fully closed.

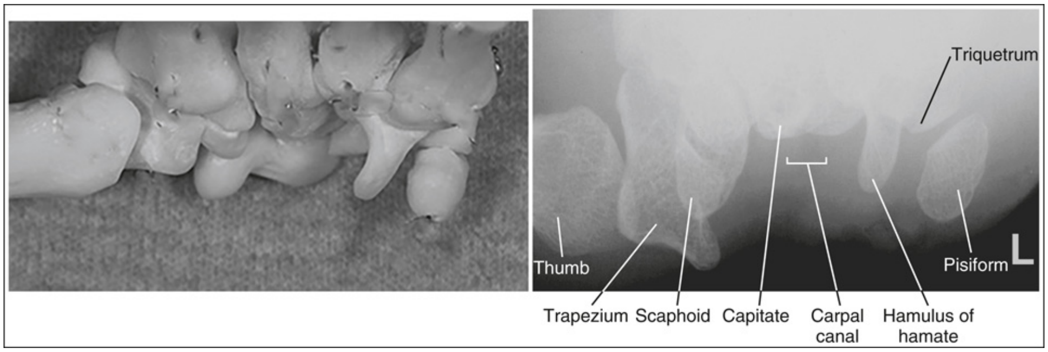


FIGURE 4.121 Tangential, inferosuperior wrist projection (carpal canal) of the wrist with accurate positioning.

TABLE 4.15

CR, Central ray; *IR*, image receptor; *PA*, posteroanterior.

Insufficient CR Angulation

If the angle between the CR and MCs is smaller than the required 15 degrees, the carpal canal is not fully demonstrated, the hamulus process is demonstrated without foreshortening, and the pisotriquetral articulation is closed (**Fig. 4.127**).

Insufficient Internal Arm Rotation

If the arm is not internally rotated enough to align the fifth MC perpendicular to the IR, the pisiform will superimpose over the hamulus process on the resulting projection (**Fig. 4.128**).

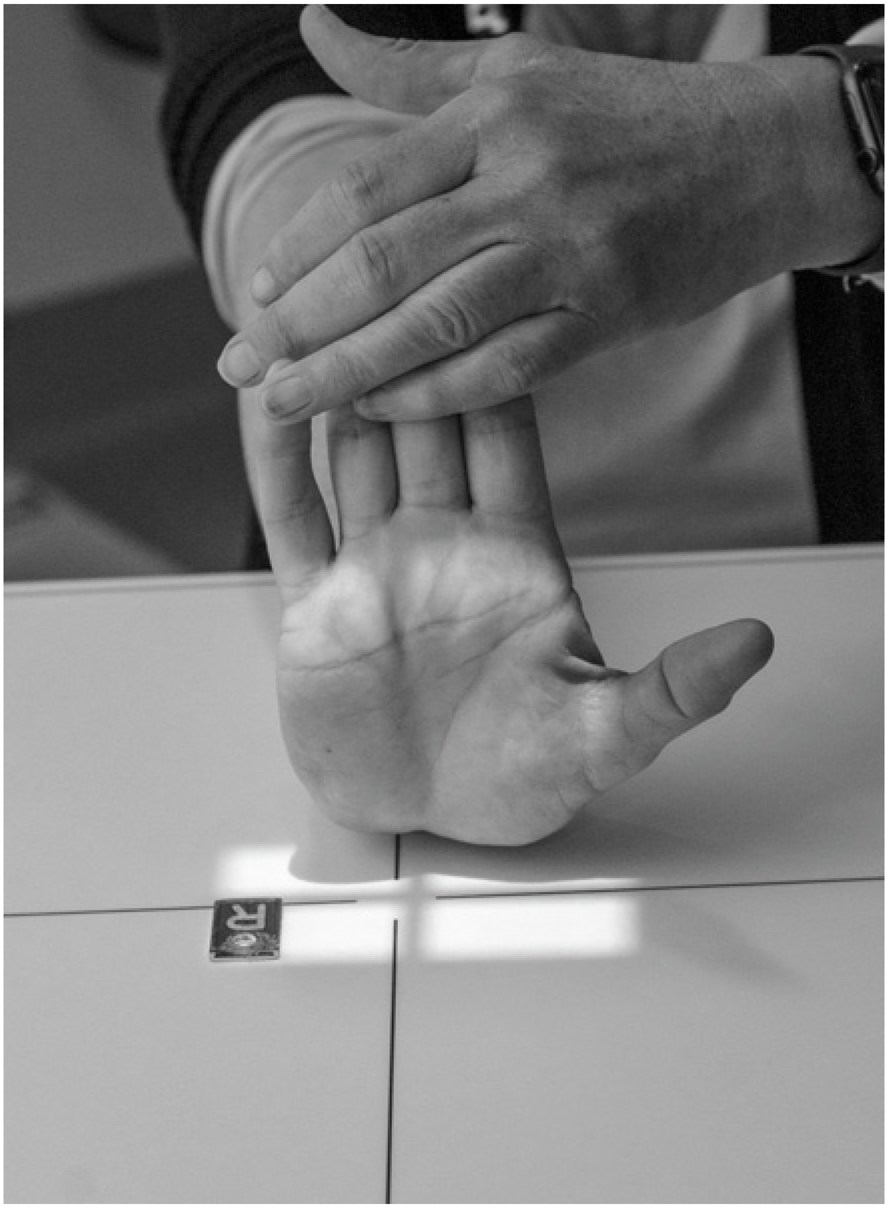


FIGURE 4.122 Proper patient positioning for the tangential, inferosuperior wrist projection (carpal canal).

image

FIGURE 4.123 Tangential, inferosuperior wrist projection (carpal canal) anatomy.

image

FIGURE 4.124 Tangential, inferosuperior wrist projection (carpal canal) CR alignment for insufficient wrist extension.

FIGURE 4.125 Tangential, inferosuperior wrist projection (carpal canal) taken with the CR and IR angle being too acute.

FIGURE 4.126 Tangential, inferosuperior wrist projection (carpal canal) taken with too great of a CR and palmar surface angle.

image

FIGURE 4.127 Tangential, inferosuperior wrist projection (carpal canal) wrist taken with too small of a CR and palmar surface angle.

FIGURE 4.128 Tangential, inferosuperior wrist projection (carpal canal) wrist taken without the fifth MC aligned perpendicular to the IR.

Carpal Canal (Tangential, Inferosuperior Projection) Analysis Practice

IMAGE 4.29

Analysis

The bases of the hamulus process and pisiform are obscured by the MC bases and the pisotriquetral articulation is not demonstrated. The angle between the CR and MCs is smaller than the required 15 degrees.

Correction

Increase the CR to MCs angle to 15 degrees.

IMAGE 4.30

Analysis

The pisiform superimposes a portion of the hamulus process. The arm was not internally rotated enough.

Correction

Internally rotate the arm until the fifth MC is aligned perpendicular to the IR.

IMAGE 4.31

Analysis

The carpal bones have been projected into the wrist and demonstrate foreshortening, and the pisotriquetral articulation demonstrates somewhat as an open space. The angle between the CR and MCs is greater than the required 15 degrees.

Correction

Decrease the CR to MCs angle to 15 degrees.

Forearm: AP Projection

See **Table 4.16** and Figs. **4.129** and **4.130**.

Distal Forearm: Internal Rotation

When the wrist and distal forearm are internally rotated, the laterally located first and second MC bases and carpal bones demonstrate superimposition, while the medially located MCs bases are seen without superimposition. The pisiform and hamulus of hamate are better

demonstrated (**Fig. 4.131**). As internal rotation increases, the degree of radial and ulnar crossover also increases (see **Fig. 4.136**).

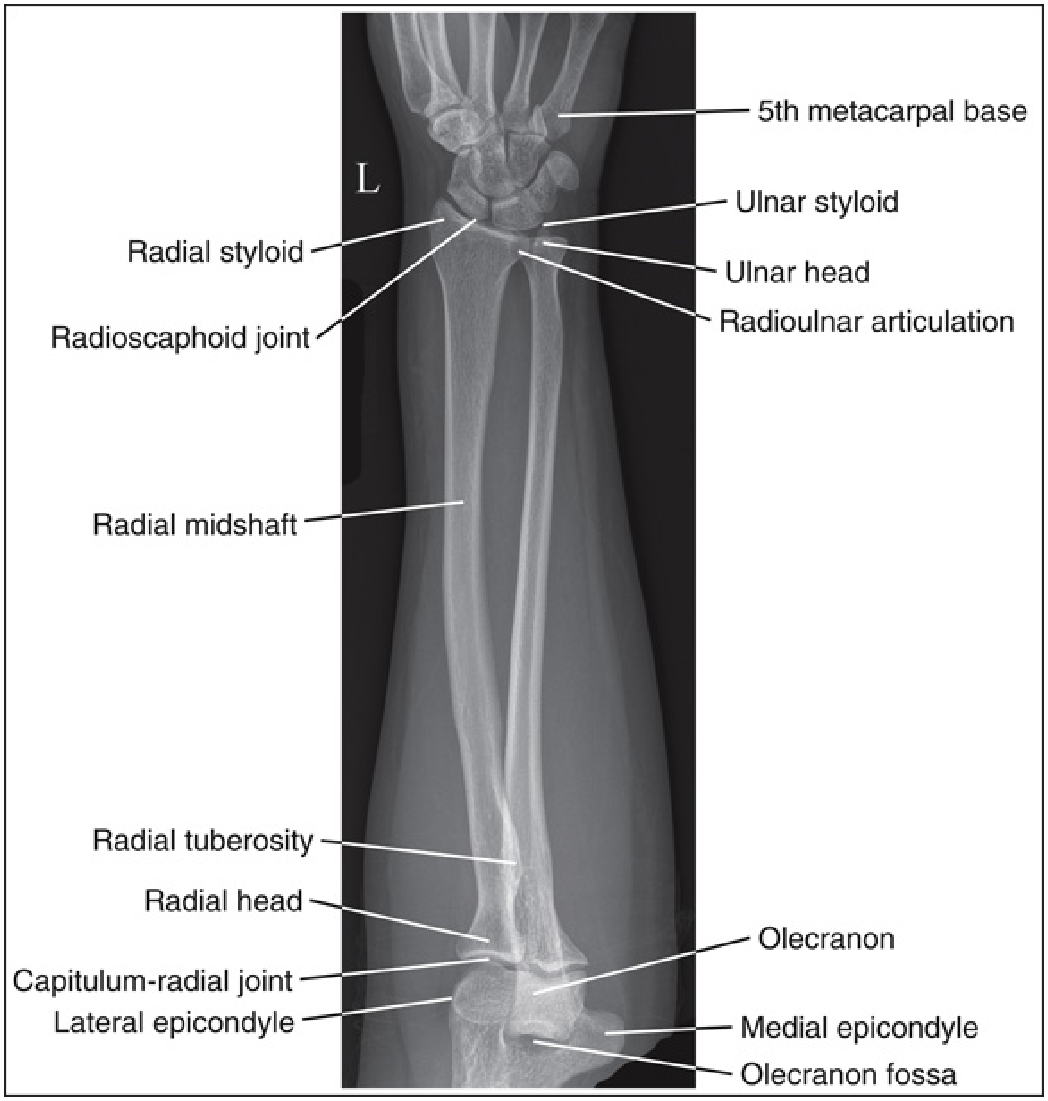


FIGURE 4.129 AP forearm projection with accurate positioning.

TABLE 4.16

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

Distal Forearm: External Rotation

If the wrist and distal forearm are externally rotated, the medially located fourth and fifth MC bases and carpal bones will be superimposed, whereas the laterally located MCs bases and carpal bones will demonstrate less superimposition. This will not occur unless the elbow is also externally rotated.

Proximal Forearm: Internal Rotation

Proximal forearm rotation results when the humeral epicondyles are poorly positioned. When more than one-eighth of the radial head is superimposed over the ulna, the elbow has been internally rotated (**Fig. 4.132**).

FIGURE 4.130 Accurate patient positioning for the AP forearm projection.

FIGURE 4.131 AP forearm projection taken with accurate elbow positioning and the wrist internally rotated.

FIGURE 4.132 AP forearm projection taken with the elbow in internal rotation.

Proximal Forearm: External Rotation

When less than one-eighth of the radial head is superimposed over the ulna, the elbow has been externally rotated (**Fig. 4.133**).

Distal Forearm: Positioning for Fracture

Patients with known or suspected forearm fractures may be unable to position both the wrist and elbow joints into an AP projection simultaneously. In such cases, position the joint closer to the fracture in a true position. When the fracture is situated closer to the wrist joint, the wrist joint and distal forearm should be accurately positioned and meet the requirements for an AP forearm projection, but the elbow and proximal forearm may demonstrate an AP oblique projection (**Fig. 4.134**). If due to a fracture the patient is unable to place the distal forearm in an AP projection, it may be taken as a PA projection. The elbow and proximal forearm will be rotated to a lateral projection (**Fig. 4.135**).

Proximal Forearm: Positioning for Fracture

When the fracture is situated closer to the elbow joint, the elbow joint and proximal forearm should meet the requirements for an AP projection, whereas the wrist and distal forearm may demonstrate an AP or PA oblique or lateral projection (**Fig. 4.136**).

FIGURE 4.133 AP forearm projection taken with the elbow externally rotated.

FIGURE 4.134 AP forearm projection with distal radial fracture.

FIGURE 4.135 A forearm projection taken with the wrist in a PA projection and the elbow in a lateral projection, and demonstrating an ulnar fracture.

FIGURE 4.136 AP forearm projection demonstrating AP elbow and lateral wrist projections.

AP Forearm Analysis Practice

IMAGE 4.32

Analysis

The elbow has been accurately positioned. The first and second MC bases and the laterally located carpal bones are superimposed, and the medially located carpal bones and pisiform are well demonstrated. The wrist was internally rotated. The proximal and distal aspects of the forearm do not demonstrate even brightness. The proximal forearm was positioned at the anode end of the tube.

Correction

While maintaining the AP projection of the elbow, rotate the wrist and hand externally until the hand and wrist are in an AP projection. Position the distal forearm at the anode end of the tube to take advantage of anode heel effect.

image

IMAGE 4.33

Analysis

The laterally located first and second MC bases and the carpal bones are superimposed, and the medially located carpals are better demonstrated. The wrist was internally rotated. Less than one-eighth of the radial head is superimposed over the ulna. The elbow was externally rotated. The proximal and distal aspects of the forearm do not demonstrate even brightness. The proximal forearm was positioned at the anode end of the tube.

Correction

Rotate the wrist and hand externally until they are in an AP projection, and rotate the elbow internally until the humeral epicondyles are parallel with the IR. Position the distal forearm at the anode end of the tube to take advantage of anode heel effect.

Forearm: Lateral Projection (Lateromedial)

See **Table 4.17** and Figs. **4.137** and **4.138**.

Distal Forearm: Internal Rotation

If the wrist and distal forearm are internally rotated instead of being in a lateral projection, the distal radius is demonstrated anterior to the ulna (**Fig. 4.139**).

Distal Forearm: External Rotation

If the wrist and distal forearm are externally rotated, the radius is visible posterior to the ulna. This will not occur without accompanying elbow rotation that is caused by the forearm and humerus not being placed on the same horizontal plane.

Humeral Epicondyle Positioning

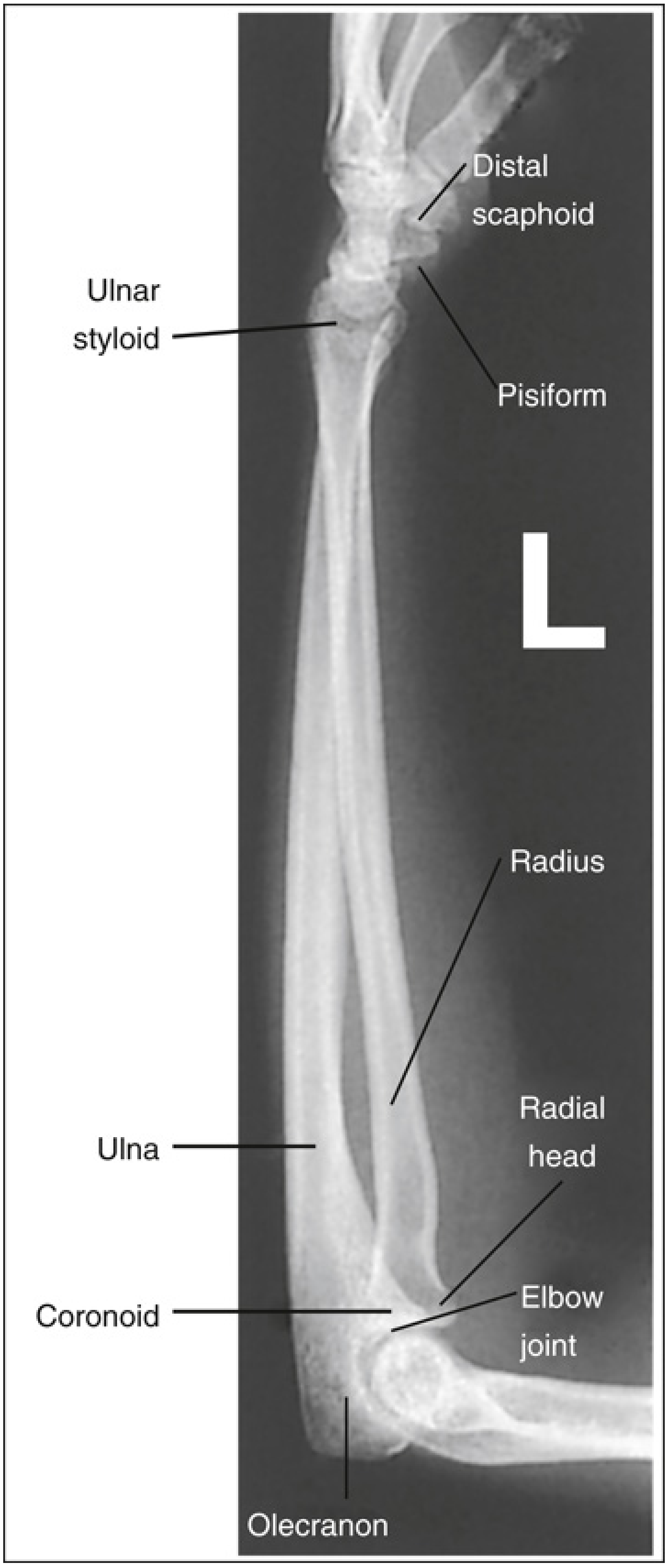
Accurate humeral epicondyle positioning aligns the anterior aspects of the radial head and coronoid process. If the proximal humerus is elevated (**Fig. 4.140**), preventing proper humeral epicondyle alignment, the anterior aspect of the radial head is positioned posterior to the coronoid process, and the proximal radius and ulna demonstrate increased superimposition (**Fig. 4.141**). If the proximal humerus is depressed, preventing proper humeral epicondyle alignment, the anterior aspect of the radial head is positioned anterior to the coronoid process.

CR Centering and Openness of Elbow Joint Space

To obtain an open elbow joint on a lateral elbow projection, the distal forearm is elevated as needed to align the humeral epicondyles perpendicular to the IR. This same alignment is not performed for the lateral forearm projection and yet in most cases the elbow joint will be demonstrated as an open space. This occurs because the CR is centered to the midforearm and the diverged x-rays used to image the elbow align parallel with the slant of the humeral epicondyles and the elbow joint space (**Fig. 4.142**).

TABLE 4.17

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.



Distal scaphoid
Ulnar styloid
Pisiform
L
Radius
Radial head
Ulna
Coronoid
Elbow joint
Olecranon

FIGURE 4.137 Lateral forearm projection with accurate positioning.

image

FIGURE 4.138 Proper patient positioning for lateral forearm projection.

FIGURE 4.139 Lateral forearm projection taken with the wrist internally rotated and the elbow flexed less than 90 degrees.

FIGURE 4.140 Lateral forearm projection taken with the proximal humerus positioned higher than the distal humerus.

image

FIGURE 4.141 Lateral forearm projection taken with the proximal humerus elevated.

image

FIGURE 4.142 Lateral humerus illustration to demonstrate alignment of x-ray divergence with the wrist and elbow joints.

Positioning for Fracture

Patients with known or suspected fractures may be unable to position both the wrist and elbow joint into a lateral projection simultaneously. In such cases, position the joint closest to the fracture in the lateral projection (**Fig. 4.143**).

Lateral Forearm Analysis Practice

image

IMAGE 4.34

image

FIGURE 4.143 Lateral forearm projection demonstrating a distal radial fracture.

Analysis

The elbow is accurately positioned. The distal radius is anterior to the ulna. The wrist was internally rotated.

Correction

Externally rotate the wrist until it is in a lateral projection.

image

IMAGE 4.35

Analysis

The distal radius is anterior to the ulna. The wrist was internally rotated. The anterior aspect of the radial head is positioned posterior to the anterior coronoid process, and the proximal radius and ulna demonstrate increased superimposition. The elbow was not bent 90 degrees and the elbow was internally rotated to only about 45 degrees. The same results would have occurred if the elbow was bent 90 degrees and the proximal humerus was elevated.

Correction

Externally rotate the wrist until it is in a lateral projection and increase the degree of internal elbow rotation until the elbow is lateral.

Elbow: AP Projection

See **Table 4.18** and Figs. **4.144** and **4.145**.

Internal Elbow Rotation

If the humeral epicondyles are not positioned in profile for the AP elbow projection, more than one-eighth (0.25 inch) of radial head is superimposed over the ulna, and the elbow was internally rotated (**Fig. 4.146**).

External Elbow Rotation

If the humeral epicondyles are not positioned in profile for the AP elbow projection, less than one-eighth (0.25 inch) of the radial head is superimposed over the ulna, and the elbow has been externally rotated (Figs. **4.147** and **4.148**).

image

FIGURE 4.144 AP elbow projection with accurate positioning.

TABLE 4.18

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

image

FIGURE 4.145 Proper patient positioning for AP elbow projection.

image

FIGURE 4.146 AP elbow projection taken with the elbow in internal rotation.

Radial Tuberosity

When the humeral epicondyles are parallel with the IR, the visualization of the radial tuberosity and the alignment of the radius and ulna with each other is determined by the position of the wrist. One way to keep track of where the radial tuberosity is when the wrist is rotated from an AP projection is to know that the thumb and radial tuberosity are on opposite sides of the ulna and that they remain on opposites sides when the wrist is rotated (**Fig. 4.149**).

- AP projection of the wrist places the thumb laterally and the radial tuberosity in profile medially, and it aligns the radius and ulna parallel with each other.
- As the distal forearm is internally rotated from an AP to a lateral projection, the thumb is pointing upwardly and the radial tuberosity rotates posteriorly, beneath the ulna, and is no longer in profile when the wrist is in a lateral projection. There is also increased superimposition of the radius (**Fig. 4.150**).
- As the distal forearm is externally rotated from an AP projection, the radial tuberosity rotates anteriorly out of profile.

Elbow Flexion

Flexion of the elbow joint on an AP elbow projection foreshortens elbow structures and draws the olecranon from the olecranon process. How the humerus and forearm are positioned in respect to the IR for an AP flexed elbow projection determines which elbow structures are foreshortened.

- *Humerus is parallel with the IR and the distal forearm is elevated* (**Fig. 4.151**). The resulting projection demonstrates an undistorted distal humerus, a foreshortened proximal forearm, a closed elbow

joint space, and the radial head articulating surface demonstrated partially on-end (**Fig. 4.152**).

- *Forearm is parallel with the IR and the proximal humerus is elevated* (**Fig. 4.153**). The resulting projection demonstrates an undistorted proximal forearm, an open elbow joint space, and a foreshortened distal humerus (**Fig. 4.154**).

image

FIGURE 4.147 AP elbow projection taken with the elbow in external rotation.

image

FIGURE 4.148 Pediatric AP elbow projection taken with the elbow in external rotation and slight flexion.

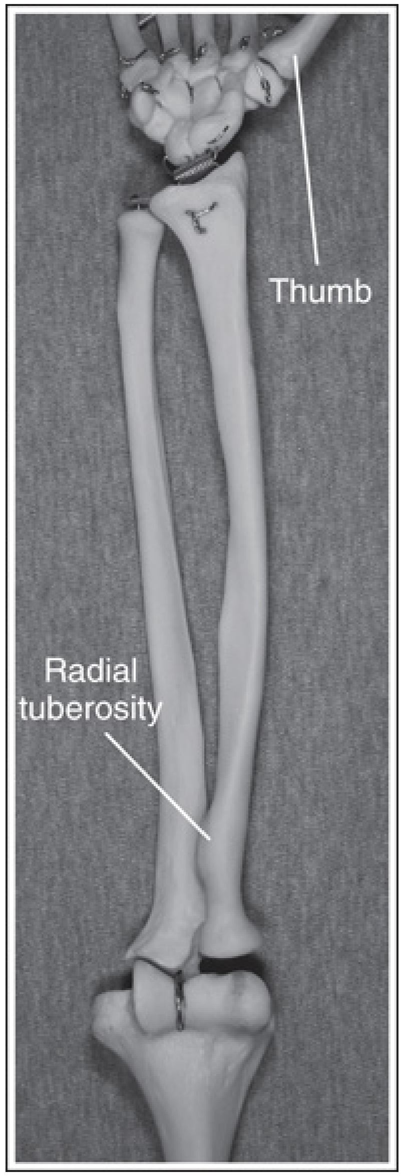


FIGURE 4.149 The thumb and radial tuberosity are located on opposite sides of the ulna and remain on opposite sides as the wrist is rotated. The location of the thumb during positioning can be used to determine if the radial tuberosity will be in profile or not on the resulting projection.

- *Flexed elbow is resting on the posterior point of the olecranon with the proximal humerus and the distal forearm elevated* (**Fig. 4.155**).

The resulting projection demonstrates a foreshortened humerus and forearm, a closed elbow joint space, and the radial head articulating surface seen partially on-end. The severity of the distortion increases with increased elbow flexion.

Positioning for the Flexed Elbow

An AP elbow projection that cannot be fully extended should be obtained using two separate exposures as demonstrated in Figs. **4.151** and **4.153**. When evaluating the projections for accuracy use only the image analysis guidelines that pertain to the part that was positioned parallel with the IR. The elbow joint space will be demonstrated as an open space only when the forearm is positioned parallel with the IR.

image

FIGURE 4.150 AP elbow projection taken with the distal forearm internally rotated until the hand and wrist are in a PA oblique projection.

image

FIGURE 4.151 Patient positioning for nonextendable AP elbow projection. The humerus is parallel with the IR.

CR Centering and Elbow Joint Openness

To obtain the desired open elbow joint space along with the forearm being placed parallel with the IR as described, the CR also needs to be centered

and aligned parallel with the elbow joint. When the CR is centered proximal to the elbow joint, beam divergences cause the capitulum to project into the joint and when the CR is centered distal to the elbow joint, the radial head is projected into the joint space (**Fig. 4.156**). Poor CR placement also foreshortens the radial head, causing its articulating surface to be demonstrated. The degree of joint closure depends on how far the CR is positioned from the elbow joint and the SID used, as these determine how diverged the x-rays will be that record the elbow joint. The farther away from the joint the CR is centered, the more the elbow joint space is obscured and the more of the radial head articulating surface is demonstrated.

image

FIGURE 4.152 AP elbow projection taken with the humerus positioned parallel with the IR and the distal forearm elevated.

image

FIGURE 4.153 Patient positioning for nonextendable AP elbow projection. The forearm is parallel with the IR.

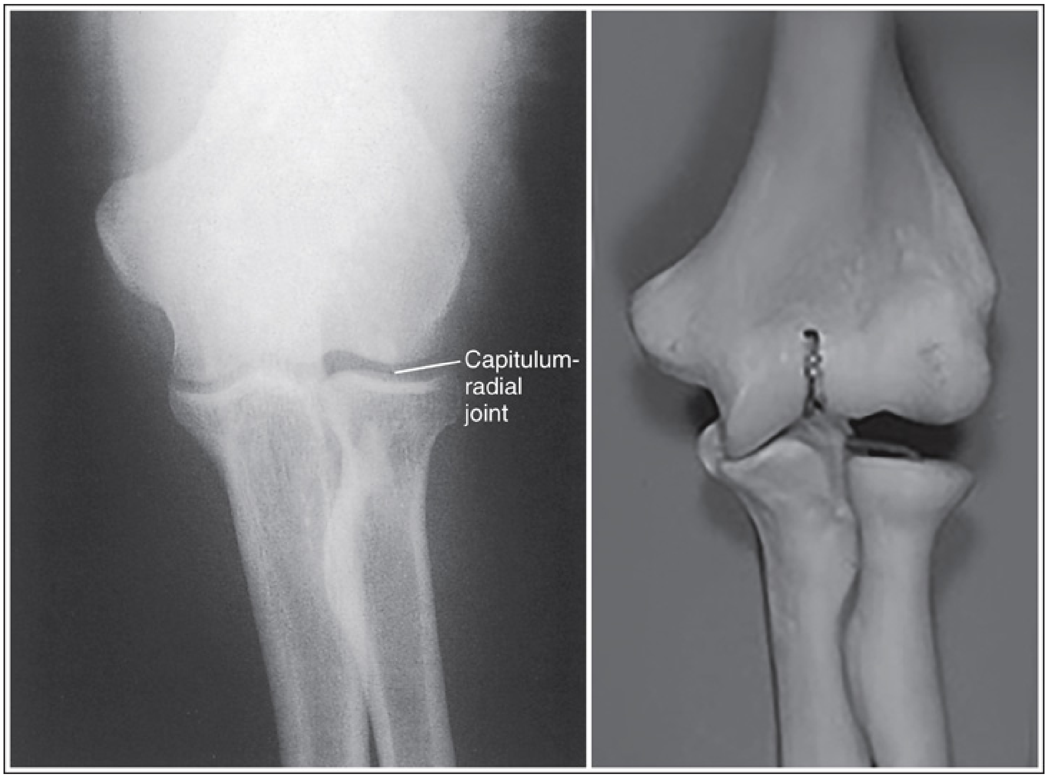


FIGURE 4.154 AP elbow projection taken with the proximal humerus elevated and the forearm positioned parallel with the IR.

FIGURE 4.155 Poor positioning for the nonextendable AP elbow projection.

image

FIGURE 4.156 AP elbow projection taken with the CR centered distal to the joint space and demonstrating a closed elbow joint space.

AP Elbow Analysis Practice

IMAGE 4.36

Analysis

The humeral epicondyles are not in profile and more than one-eighth of the radial head is superimposed over the ulna. The elbow was internally rotated.

Correction

Rotate the elbow externally until the humeral epicondyles are parallel with the IR.

IMAGE 4.37

Analysis

The humeral epicondyles are not in profile and less than one-eighth of the radial head is superimposing the ulna. The elbow was externally rotated.

Correction

Rotate the elbow internally until the humeral epicondyles are parallel with the IR.

image

IMAGE 4.38

Analysis

The distal humerus is demonstrated without foreshortening, but the proximal forearm is severely distorted. The humerus was positioned parallel with the IR and the distal forearm was elevated.

Correction

If possible, fully extend the elbow. If the patient is unable to extend the elbow, this is an acceptable projection of the distal humerus. A second AP projection of the elbow should be taken with the forearm positioned parallel with the IR.

Elbow: AP Oblique Projections (Medial and Lateral Rotation)

See **Table 4.19** and Figs. **4.157**–**4.160**.

Medial Oblique: Insufficient Medial Obliquity

If the humeral epicondyles are at less than 45 degrees of obliquity with the IR for a medial oblique elbow, less than three-fourths of the radial head superimposes the ulna (**Fig. 4.161**).

Medial Oblique: Excessive Medial Obliquity

If the humeral epicondyles are at more than 45 degrees of obliquity with the IR for a medial oblique elbow, more than three-fourths of the radial head superimposes the ulna (**Fig. 4.162**).

Lateral Oblique: Insufficient Medial Oblique

If the humeral epicondyles are at less than 45 degrees of obliquity with the IR for a lateral oblique elbow, the radial head and/or the radial tuberosity still partially superimpose the ulna (**Fig. 4.163**).

Lateral Oblique: Excessive Medial Oblique

If the humeral epicondyles are at more than 45 degrees of obliquity with the IR for a lateral oblique projection, the coronoid process partially superimposes the radial head, the radial tuberosity and ulna demonstrate no superimposition, and the radial tuberosity is no longer in partial profile (**Fig. 4.164**).

Elbow Flexion

- *Humerus is parallel with the IR and the distal forearm is elevated.* The resulting projection demonstrates an undistorted distal humerus, a foreshortened proximal forearm, a closed capitulum-radial head (lateral oblique) or trochlear-coronoid process (medial oblique) joint space, and the articulating surfaces of the radial head (lateral oblique) or trochlea (medial oblique) (**Fig. 4.165**).
- *Forearm is parallel with the IR and the proximal humerus is elevated.* The projection shows an undistorted proximal forearm, an open capitulum-radial head (lateral oblique) or trochlear-coronoid process (medial oblique) joint space, and a foreshortened distal humerus (**Fig. 4.166**).
- *Flexed elbow is resting on the posterior point of the olecranon with the proximal humerus and the distal forearm elevated.* Both the humerus and the forearm are foreshortened as described above.

The severity of the distortion increases with increased elbow flexion (**Fig. 4.167**).

FIGURE 4.157 AP medial oblique elbow projection with accurate positioning.

TABLE 4.19

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

Positioning for the Flexed Elbow

For AP oblique elbow projections, if the patient's condition prevents full elbow extension, the anatomic structure (forearm or humerus) of greatest interest is positioned parallel with the IR. This is discerned by obtaining a good patient history and looking at images obtained in the past of the same structure. If the radial head or coronoid process is of interest, position the forearm parallel with the IR (**Fig. 4.168**). If the capitulum or medial trochlea is of interest, position the humerus parallel with the IR. When evaluating the projections, follow the image analysis guidelines that relate to the structure (forearm or humerus) that was positioned parallel with the IR to determine projection acceptability. The elevated forearm or humerus, respectively, will demonstrate foreshortening and will be of less value for diagnosis.

image

FIGURE 4.158 AP lateral oblique elbow projection with accurate positioning.

image

FIGURE 4.159 Proper patient positioning for AP medial oblique elbow projection.

image

FIGURE 4.160 Proper patient positioning for AP lateral oblique elbow projection.

image

FIGURE 4.161 AP medial oblique elbow projection taken with less than 45 degrees of elbow obliquity.

image

FIGURE 4.162 AP medial oblique elbow projection taken with more than 45 degrees of elbow obliquity.

image

FIGURE 4.163 AP lateral oblique elbow projection taken with less than 45 degrees of elbow obliquity and the distal forearm slightly elevated.

image

FIGURE 4.164 AP lateral oblique elbow projection taken with more than 45 degrees of elbow obliquity.

image

FIGURE 4.165 AP lateral oblique elbow projection taken with the distal forearm elevated.

FIGURE 4.166 AP lateral oblique elbow projection taken with the proximal humerus elevated, causing the humerus to be tilted with the IR, and the forearm aligned parallel with the IR.

image

FIGURE 4.167 AP lateral oblique elbow projection obtained with the flexed elbow resting on the posterior point of the olecranon. Proximal humerus and distal forearm were elevated.

image

FIGURE 4.168 Proper patient positioning for AP medial oblique elbow projection with a flexed elbow.

CR Centering: Joint Space Openness

To obtain the desired open elbow joint space along with the forearm being placed parallel with the IR as described above, the CR also needs to be centered and aligned parallel with the elbow joint. When the CR is centered proximal to the joint spaces, the structures of the distal humerus are projected into the joints, and when the CR is centered distal to the joint spaces, the structures of the proximal forearm are projected into the joint spaces (**Fig. 4.169**).

image

FIGURE 4.169 AP lateral oblique elbow projection taken with the CR centered distal to the elbow joint space.

AP Oblique Elbow Analysis Practice

image

IMAGE 4.39 Lateral oblique projection.

Analysis

The capitulum-radial head joint space is closed and the radial head articulating surface is demonstrated. The elbow was not fully extended.

Correction

Fully extend the elbow. If the patient is unable to extend the elbow and the proximal forearm is of interest, position the forearm parallel with the IR.

image

IMAGE 4.40 Medial oblique projection.

Analysis

The radial head is entirely superimposed on the ulna. Elbow obliquity was more than 45 degrees.

Correction

Decrease the degree of internal elbow rotation until the humeral epicondyles are angled at 45 degrees with the IR.

image

IMAGE 4.41 Lateral oblique projection.

Analysis

The radial head and tuberosity are partially superimposed over the ulna. The degree of elbow obliquity was less than 45 degrees.

Correction

Increase the degree of external elbow rotation until the humeral epicondyles are angled at 45 degrees with IR.

Elbow: Lateral Projection (Lateromedial)

See **Table 4.20** and Figs. **4.170** and **4.171**.

Elbow Soft Tissue Structures

To evaluate a lateral elbow projection, the reviewer not only analyzes the bony structure, but also studies the placement of the soft tissue fat pads. There are three fat pads of interest present on a lateral elbow projection (**Fig. 4.172**).

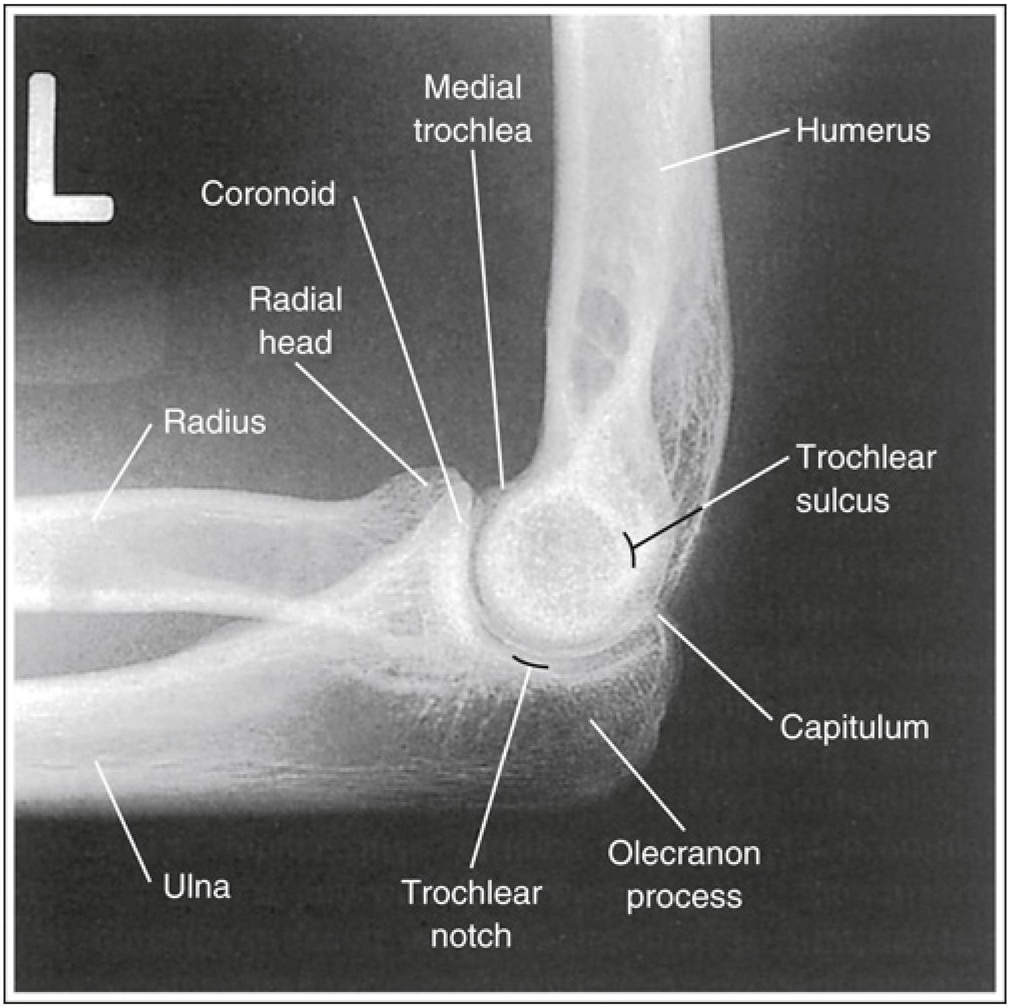


FIGURE 4.170 Lateral elbow projection with accurate positioning.

FIGURE 4.171 Proper patient positioning for lateral elbow projection.

TABLE 4.20

CR, Central ray; *IR*, image receptor.

- *Anterior fat pad* is routinely seen on lateral elbow projections when adequate exposure factors are used. This pad is situated immediately anterior to the distal humerus. A change in the shape or placement of the anterior fat pad may indicate joint effusion and elbow injury.

- *Posterior fat pad* is obscured on negative lateral elbow projections because of its location within the olecranon fossa. When an injury occurs, joint effusion pushes this pad out of the fossa, allowing it to be visualized proximal to the olecranon fossa.
- *Supinator fat stripe* is visible parallel to the anterior aspect of the proximal radius. Displacement of this fat stripe is useful for diagnosing fractures of the radial head and neck.

Elbow Flexion and Fat Pad Visualization

When the elbow is flexed 90 degrees and the forearm is elevated to align the anatomic structures of the distal humerus properly, displacement of the anterior and posterior fat pads can be used as signs to determine diagnosis. If the elbow is not adequately flexed, these fat pads can be displaced by poor positioning instead of joint pathology, interfering with their diagnostic usefulness. As the arm is extended, nonpathologic displacement of the anterior fat pad results from intraarticular pressure placed on the joint and nonpathologic displacement of the posterior fat pad is a result of positioning of the olecranon within the olecranon fossa, which causes proximal and posterior displacement of the pad (**Fig. 4.173**).

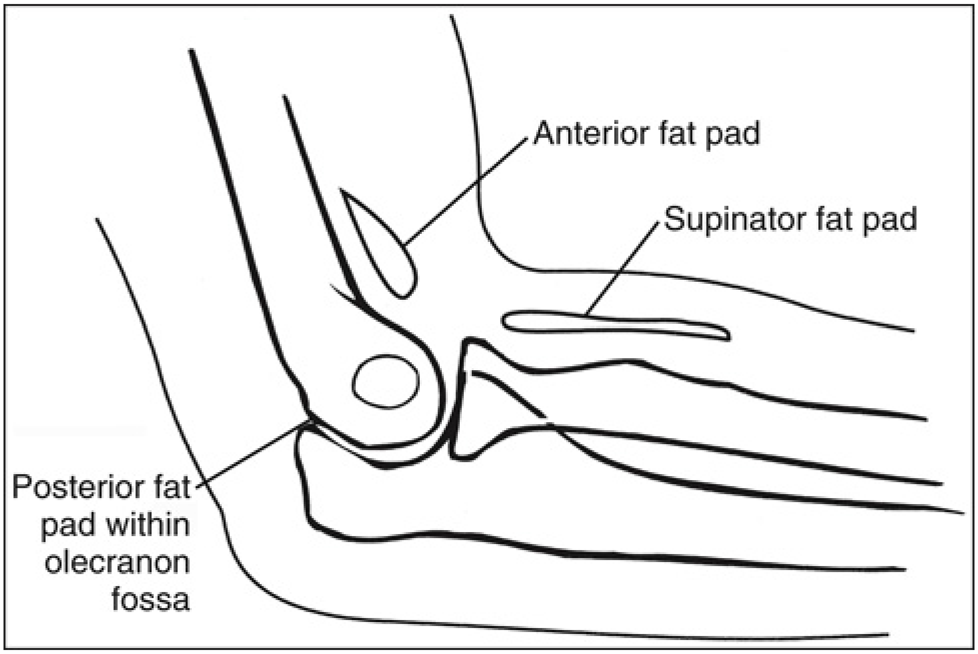


FIGURE 4.172 Locations of fat pads on lateral elbow projection.

Humeral Epicondyle Positioning

A lateral elbow projection is obtained when the proximal humerus and distal forearm are positioned so the humeral epicondyles are situated directly on top of each other, placing an imaginary line drawn between them perpendicular to the IR. This positioning aligns the trochlear sulcus, capitulum, and medial trochlea into three concentric (having the same center) arcs (**Fig. 4.174**). The trochlear sulcus is the small center arc. It moves very little when a positional change is made and works like a pivoting point between the capitulum and medial aspect of the trochlea. The largest of the arcs is the medial aspect of the trochlea. It is demonstrated very close to and slightly superimposed on the curve of the trochlear notch. The intermediate-sized arc is the capitulum. When these three arcs are in accurate alignment, the elbow joint is visualized as an open space and the

anterior and proximal surfaces of the radial head and coronoid process are aligned.

FIGURE 4.173 Lateral elbow projection taken with the elbow extended and the hand and wrist pronated.

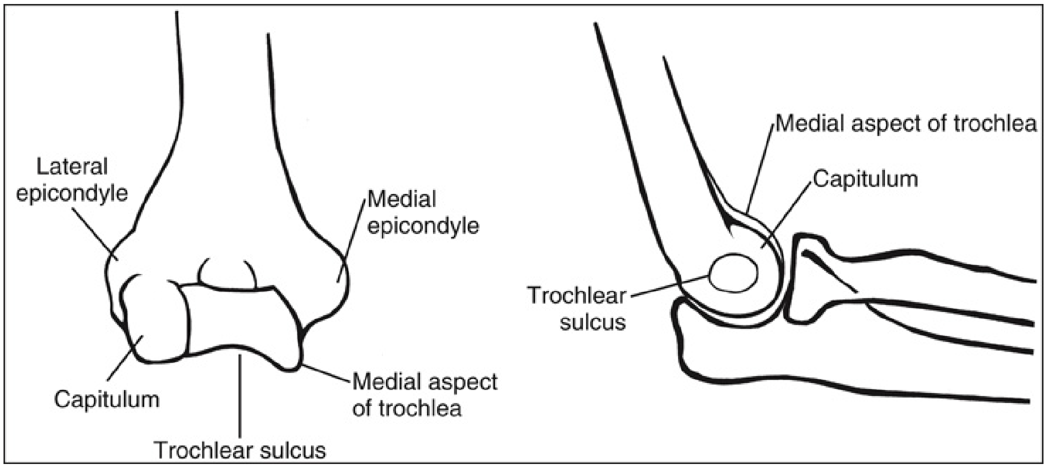


FIGURE 4.174 AP *(left)* and lateral *(right)* projections showing anatomy of the distal humerus.

Proximal humerus elevation and depression determines the alignment of the distal surfaces of the capitulum and medial trochlea, and the anterior alignment of the radial head and coronoid process, whereas distal forearm depression and elevation determines the anterior alignment of the capitulum and medial trochlea and the proximal alignment of the radial head and coronoid process. Carefully evaluate projections that show poor positioning, as both forearm and humeral corrections may be needed to obtain accurate positioning.

Proximal Humerus Elevation

If the proximal humerus is elevated (**Fig. 4.175**), the distal surface of the capitulum is demonstrated too far distal to the distal surface of the medial trochlea and the radial head is placed too far posteriorly to the coronoid process (**Fig. 4.176**).

Proximal Humerus Depressed

If the proximal humerus is depressed (**Fig. 4.177**), the distal capitulum is demonstrated too far proximal to the distal medial trochlear and the radial

head is positioned too far anteriorly to the coronoid process (Figs. **4.178** and **4.179**).

Distal Forearm Too Depressed

When the distal forearm is positioned too close to the IR (depressed) (**Fig. 4.180**), the projection shows the capitulum anteriorly to the medial trochlea and the radial head distally to the coronoid process (Figs. **4.181** and **4.182**).

Distal Forearm Too Elevated

When the distal forearm is too elevated off the IR (**Fig. 4.183**), the projection shows the capitulum posteriorly to the medial trochlea and the radial head proximally to the coronoid process (**Fig. 4.184**).

Wrist Rotation: Radial Tuberosity Visualization

- *Lateral wrist projection* situates the radial tuberosity on the medial aspect of the radius where it is superimposed by the radius and is not demonstrated in profile (**Fig. 4.185**).

FIGURE 4.175 Patient positioned for lateral elbow projection with elevated proximal humerus.

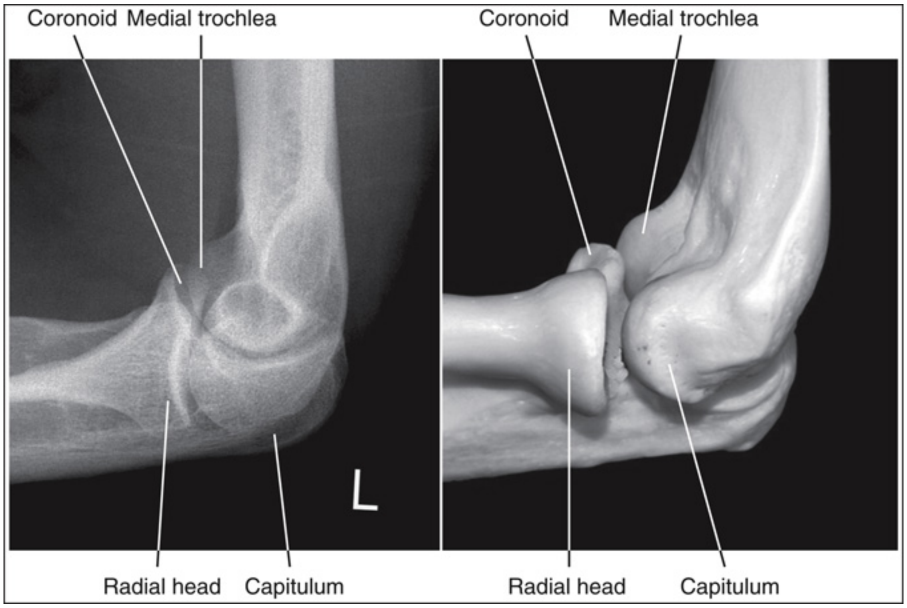


FIGURE 4.176 Lateral elbow projection taken with the proximal humerus elevated.

FIGURE 4.177 Patient positioned for lateral elbow projection with depressed proximal humerus.

- *External wrist rotation* rotates the radial tuberosity toward the anterior arm surface, where it is partially demonstrated in profile anteriorly (**Fig. 4.186**).
- *Internal wrist rotation* rotates the radial tuberosity to the posterior arm surface, demonstrating it in full or partial profile posteriorly (**Fig. 4.187**).

Alternate Projections to Demonstrate Radial Head Fractures

• *Radial head laterals-lateromedial projections.* Lateral elbow projections taken with the wrist in different positions (AP oblique, lateral, PA oblique, and PA) are often obtained to study the circumference of the radial head and neck for fractures. These projections are evaluated using the same lateral elbow guidelines listed in the preceding section with the exception of the placement of the radial tuberosity, which will change with wrist rotation as indicated above.

• *Axiolateral elbow projection* (Coyle Method) discussed next in this chapter.

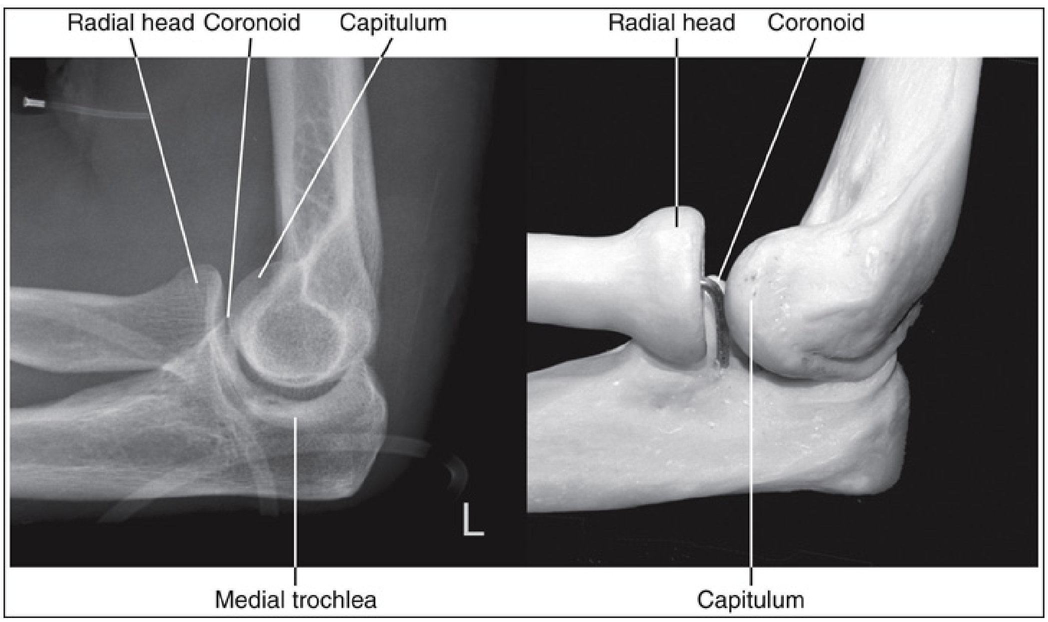


FIGURE 4.178 Lateral elbow projection taken with the proximal humerus depressed.

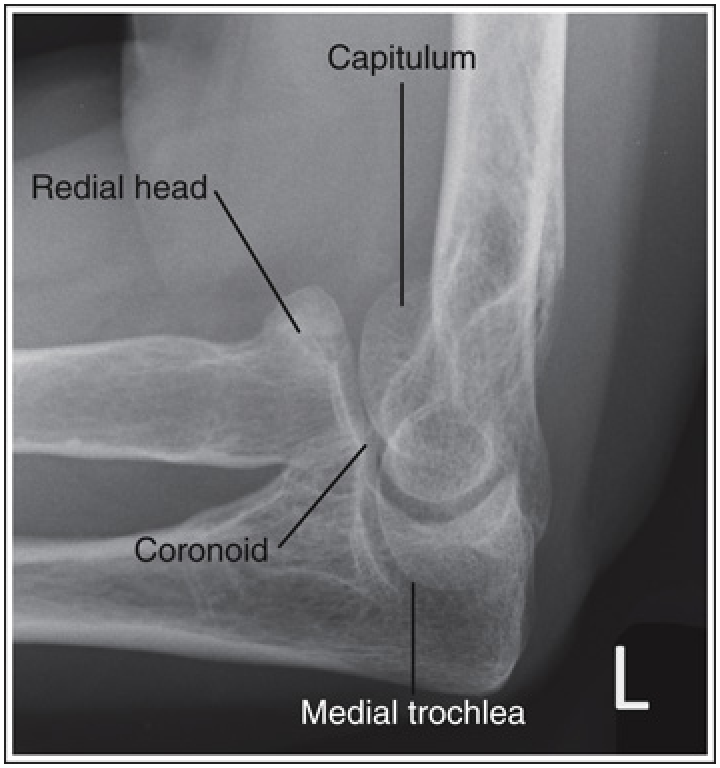


FIGURE 4.179 Lateral elbow projection taken with the proximal humerus depressed.

FIGURE 4.180 Patient positioned for lateral elbow projection with depressed distal forearm.

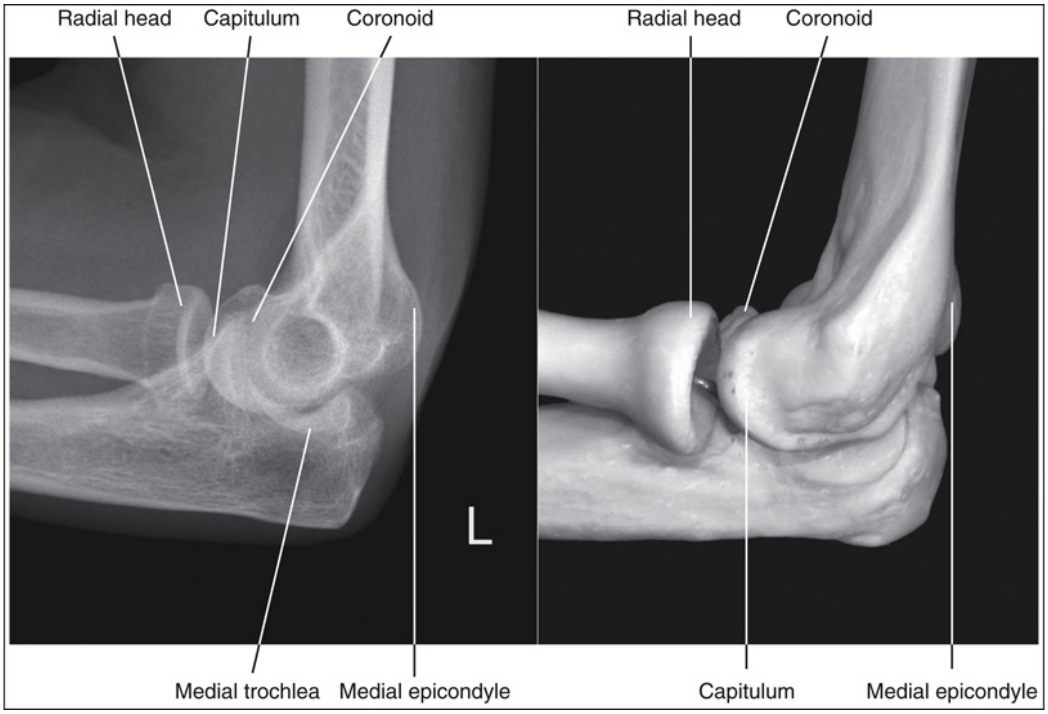


FIGURE 4.181 Lateral elbow projection taken with the distal forearm depressed.

FIGURE 4.182 Pediatric lateral elbow projection taken with the distal forearm depressed.

FIGURE 4.183 Patient positioned for lateral elbow projection with elevated distal forearm.

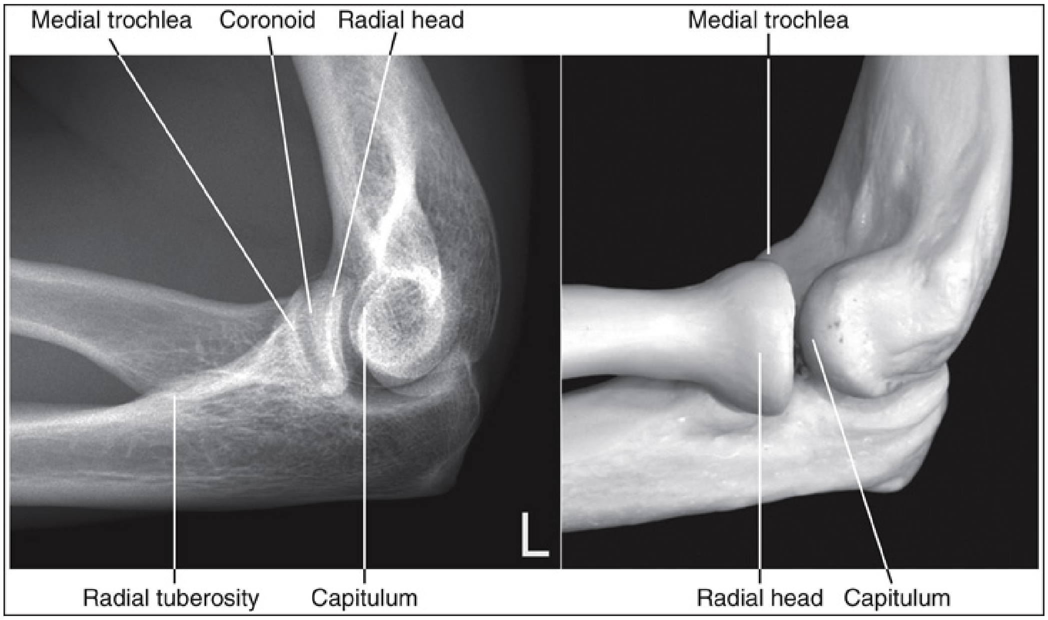


FIGURE 4.184 Lateral elbow projection taken with the distal forearm positioned too far away from the IR and the wrist internally rotated.

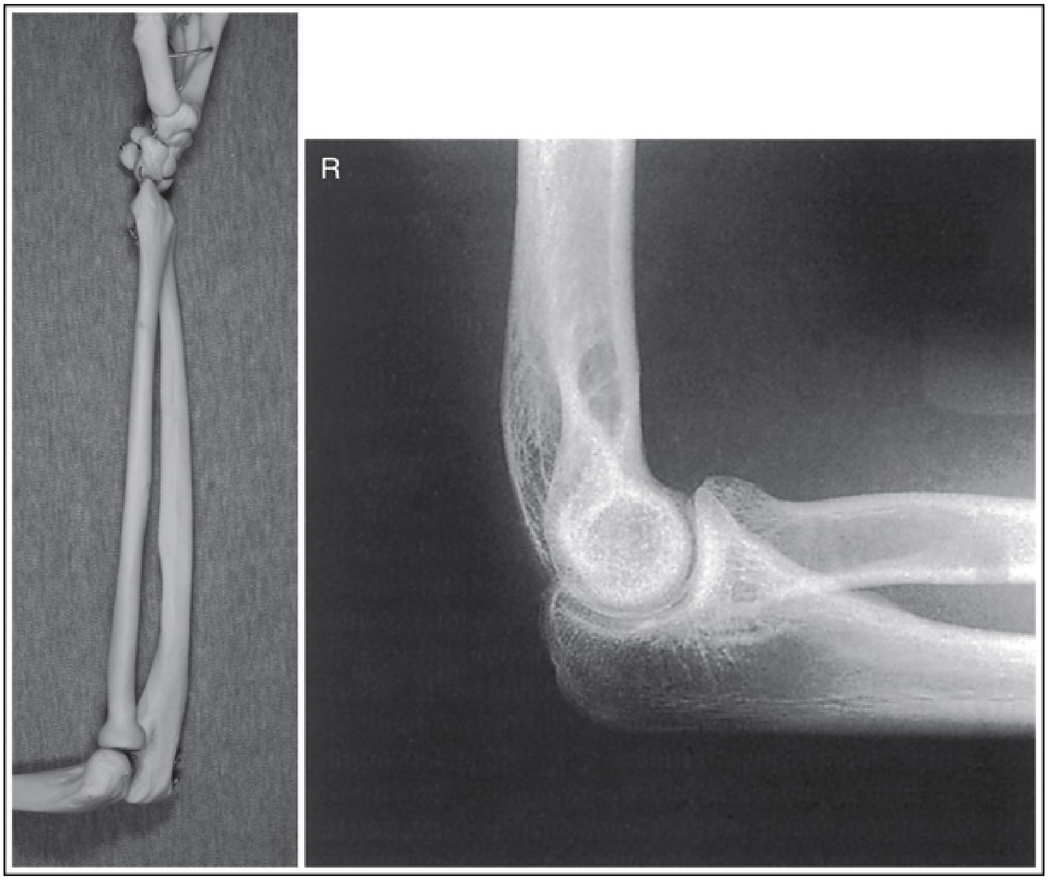


FIGURE 4.185 Lateral elbow projection taken with the wrist in a lateral projection. The radial tuberosity is superimposed by the radius.

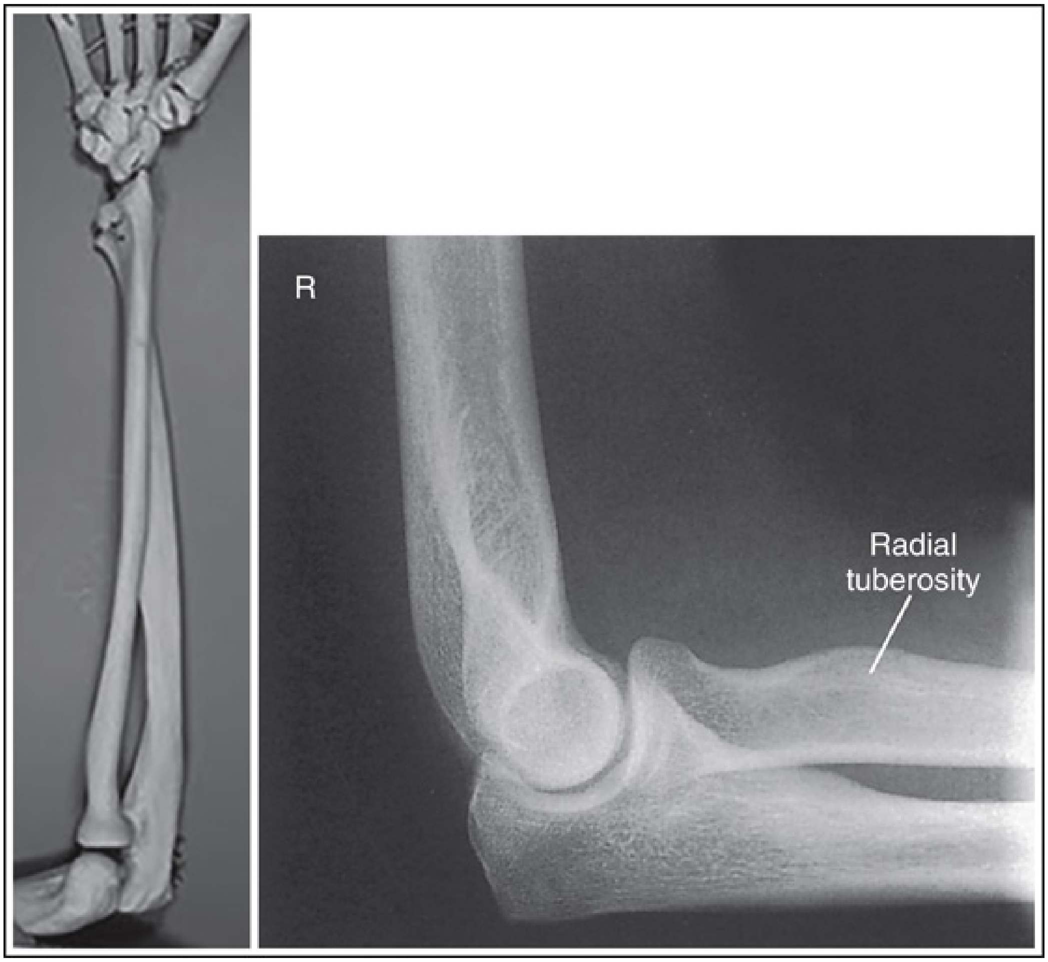


FIGURE 4.186 Lateral elbow projection taken with the wrist externally rotated. The radial tuberosity is seen in profile anteriorly.

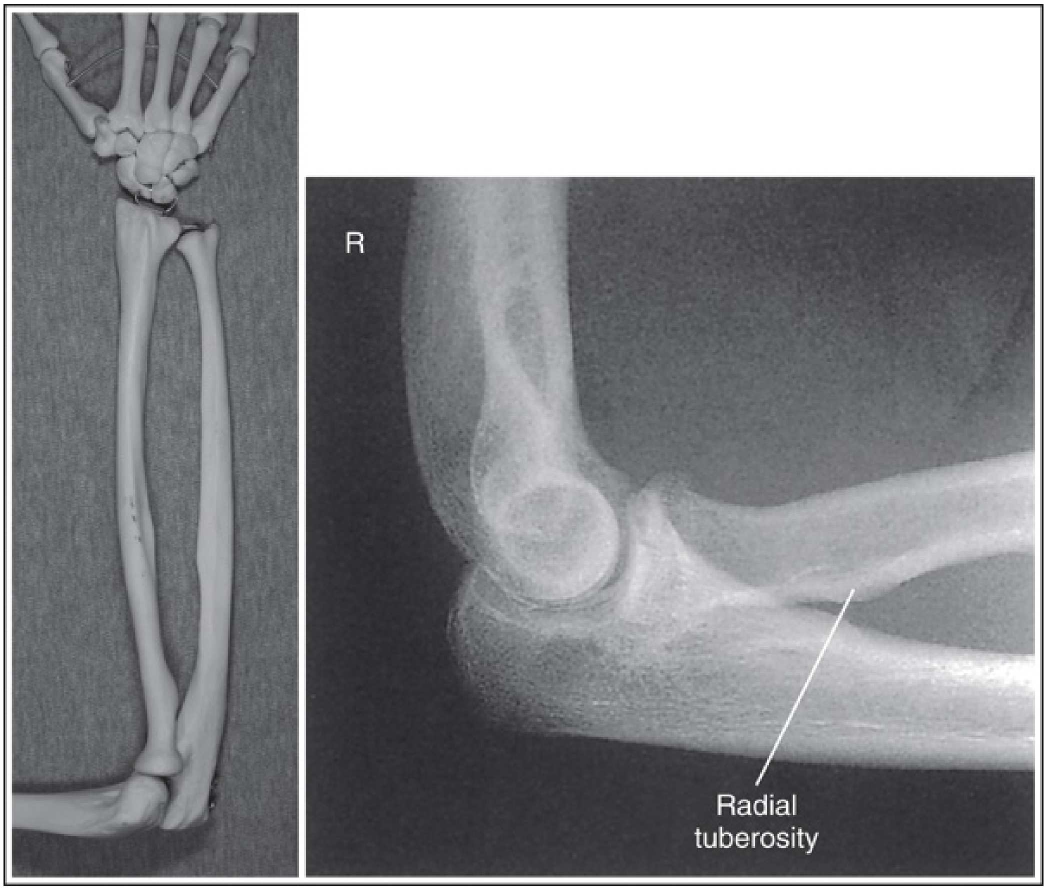


FIGURE 4.187 Lateral elbow projection taken with the wrist internally rotated. The radial tuberosity is in partial profile posteriorly.

Lateral Elbow Analysis Practice

IMAGE 4.42

Analysis

The radial head is positioned too far posterior to the coronoid process and the capitulum is positioned too far distally to the medial trochlea. The proximal humerus was too elevated.

Correction

Depress the proximal humerus until the humeral epicondyles are superimposed.

IMAGE 4.43

Analysis

The radial head is positioned too far anteriorly to the coronoid process and the capitulum is demonstrated too far proximally to the medial trochlea. The proximal humerus was too depressed.

Correction

Elevate the proximal humerus until the humeral epicondyles are superimposed.

IMAGE 4.44

Analysis

The radial head is positioned too far distal to the coronoid process and the capitulum is demonstrated too far anteriorly to the medial trochlea. The distal forearm was too depressed.

Correction

Elevate the distal forearm until the humeral epicondyles are superimposed.

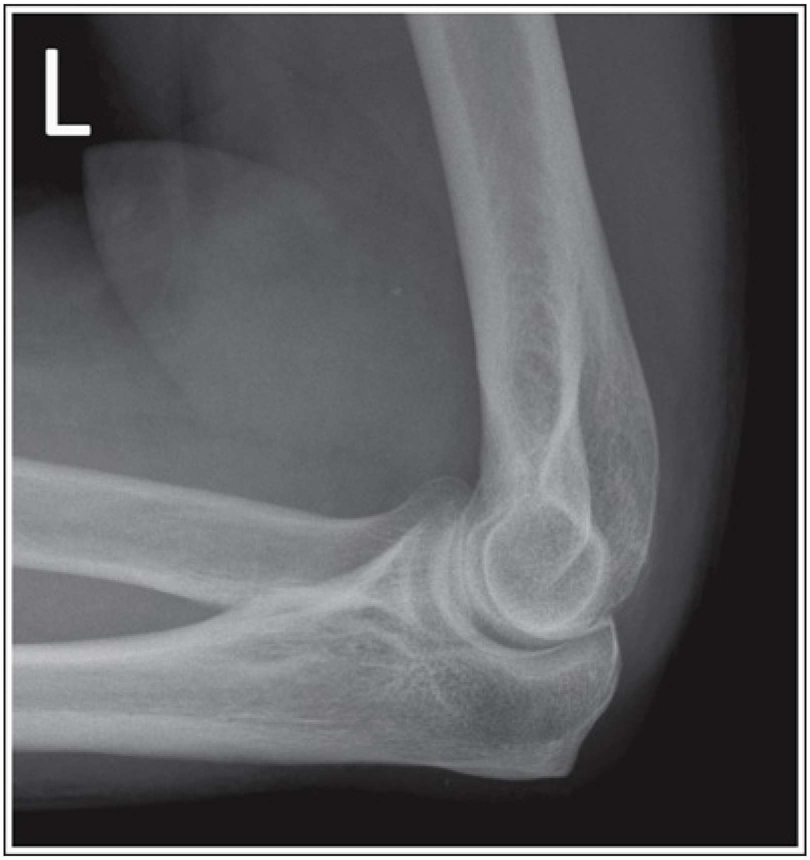


IMAGE 4.45

Analysis

The radial head is positioned too far proximal to the coronoid process and the capitulum is positioned too far posteriorly to the medial trochlea. The distal forearm was too elevated.

Correction

Depress the distal forearm until the humeral epicondyles are superimposed.

Elbow: Axiolateral Elbow Projection (Coyle Method)

See **Table 4.21** and Figs. **4.188** and **4.189**.

Exam Indication

The radial axiolateral elbow projection is a special projection taken to demonstrate fractures of the radial head and capitulum.

Elbow Flexion and CR Alignment

Accurate elbow flexion and CR alignment with the humerus and forearm are needed to accurately project the capitulum proximally to the medial trochlea and the radial head anteriorly to the coronoid. If more or less than 90 degrees of elbow flexion is used, the CR traverses the distal humerus, proximal forearm, or both at an alignment that will not move the radial head or the capitulum in the desired directions. A projection obtained with more than 90 degrees of elbow flexion and the CR accurately aligned with the proximal forearm, but poorly with the distal humerus, will accurately project the radial head anterior to the coronoid process, but it will also project it into the distal humerus, obscuring parts of the radial head and the capitulum (**Fig. 4.190**). If the patient is unable to flex the elbow to 90 degrees, the CR should be aligned perpendicular to the forearm's long axis so it is directed anteriorly to best demonstrate the radial head.

Proximal Humerus Depression or Excessive CR Angulation

If the CR is angled accurately but the proximal humerus is depressed lower than the distal humerus, the cortices of the medial trochlea and capitulum are not clearly defined, the coronoid process is free of radial head superimposition, and the proximal radius superimposes the ulnar supinator crest (a sharp, prominent ridge running along the lateral margin of the ulna that divides the ulna's anterior and posterior surfaces; **Fig. 4.191**). The same projection can also result if the patient is accurately positioned but the CR is angled more than 45 degrees.

Proximal Humerus Elevated or Inadequate CR Angulation

If the CR is accurately angled but the proximal humerus is elevated, the medial trochlea demonstrates some capitular superimposition and the radial head superimposes over more than the tip of the coronoid process (**Fig. 4.192**). The same projection can result if the patient is accurately positioned but the CR is angled less than 45 degrees.

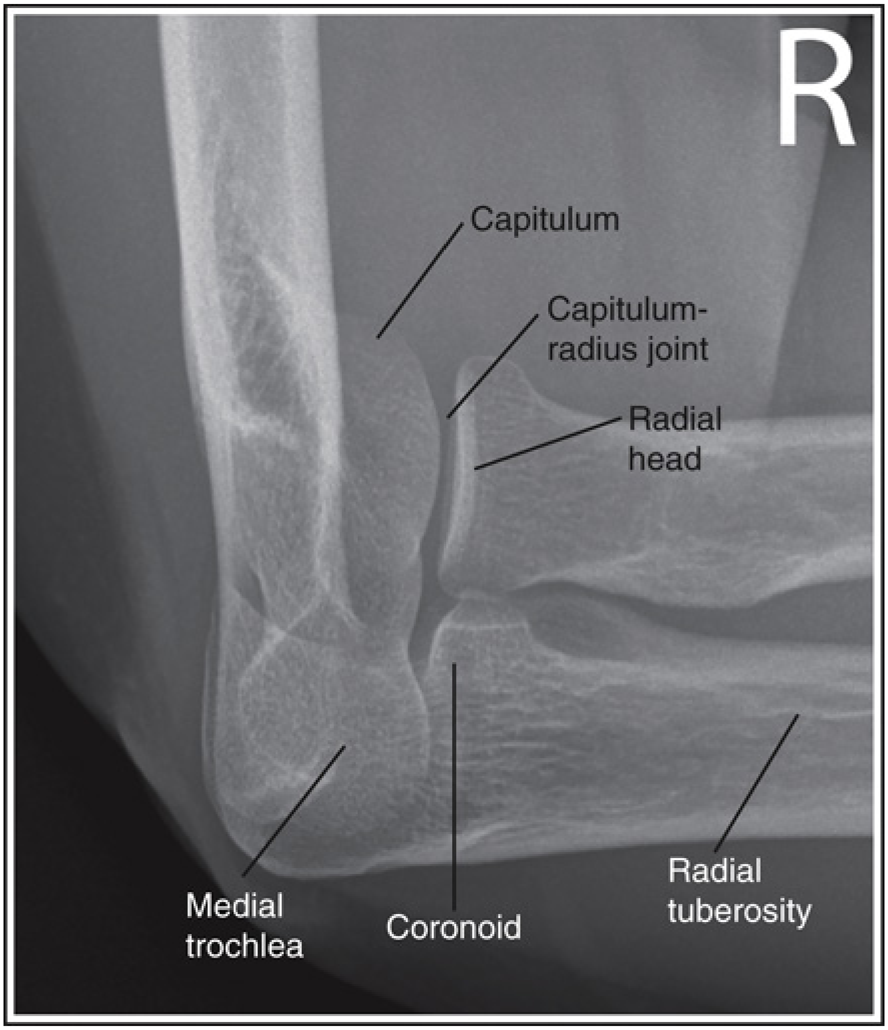


FIGURE 4.188 Axiolateral elbow projection (Coyle method) with accurate positioning.

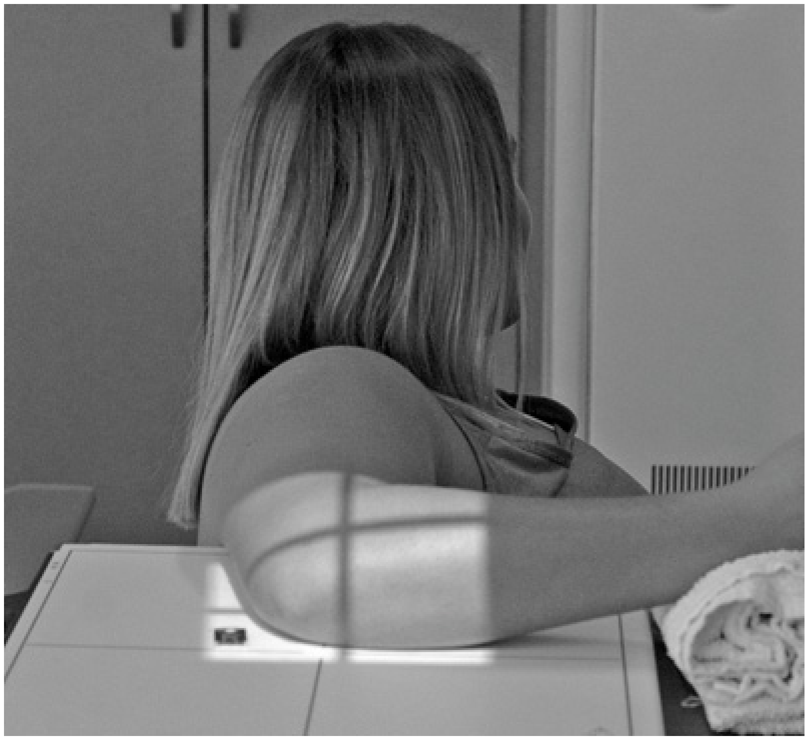


FIGURE 4.189 Proper patient positioning for axiolateral elbow projection (Coyle method).

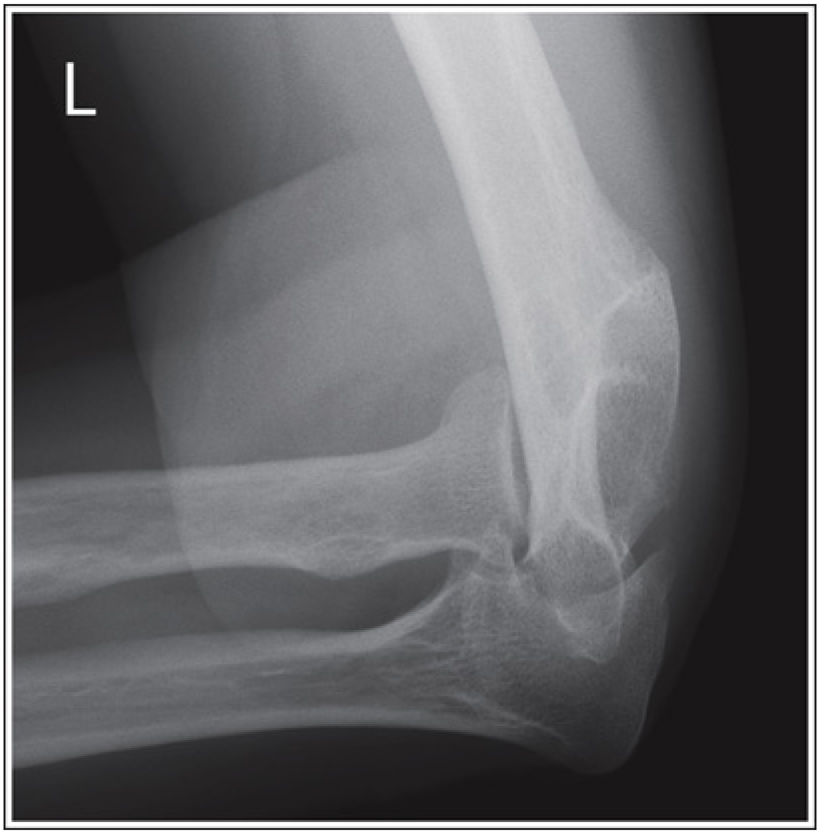


FIGURE 4.190 Axiolateral elbow projection (Coyle method) taken with the elbow flexed more than 90 degrees.

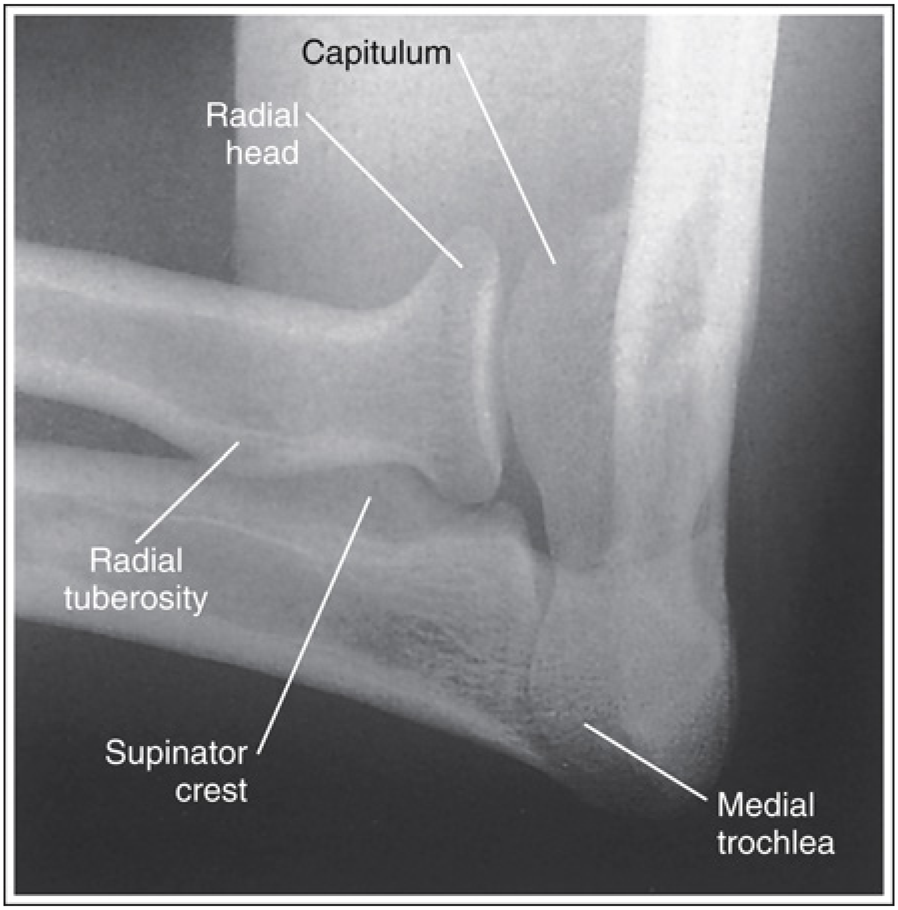


FIGURE 4.191 Axiolateral elbow projection (Coyle method) taken with the proximal humerus depressed and the radial tuberosity demonstrated in partial profile, indicating that the wrist was in a PA oblique projection.

TABLE 4.21

CR, Central ray; *IR*, image receptor; *PA*, posteroanterior.

Distal Forearm Too Depressed

The openness of the elbow joint space, the anterior alignment of the capitulum and medial trochlea, and the proximal alignment of the radial

head and coronoid process are affected when the distal forearm is positioned. If the distal forearm is too depressed, the resulting projection demonstrates a closed elbow joint space and shows the capitulum too far anterior to the medial trochlea and the radial head distal to the coronoid process (**Fig. 4.193**).

FIGURE 4.192 Axiolateral elbow projection (Coyle method) taken with the proximal humerus elevated.

FIGURE 4.193 Axiolateral elbow projection (Coyle method) taken with the distal forearm depressed and the wrist placed in a lateral projection.

Distal Forearm Too Elevated

If the distal forearm is positioned too far away from the IR, the projection shows the capitulum too far posterior to the medial trochlea and the radial head proximal to the coronoid process (**Fig. 4.194**).

FIGURE 4.194 Axiolateral elbow projection (Coyle method) taken with the distal forearm positioned too far away from the IR and the wrist in a lateral projection.

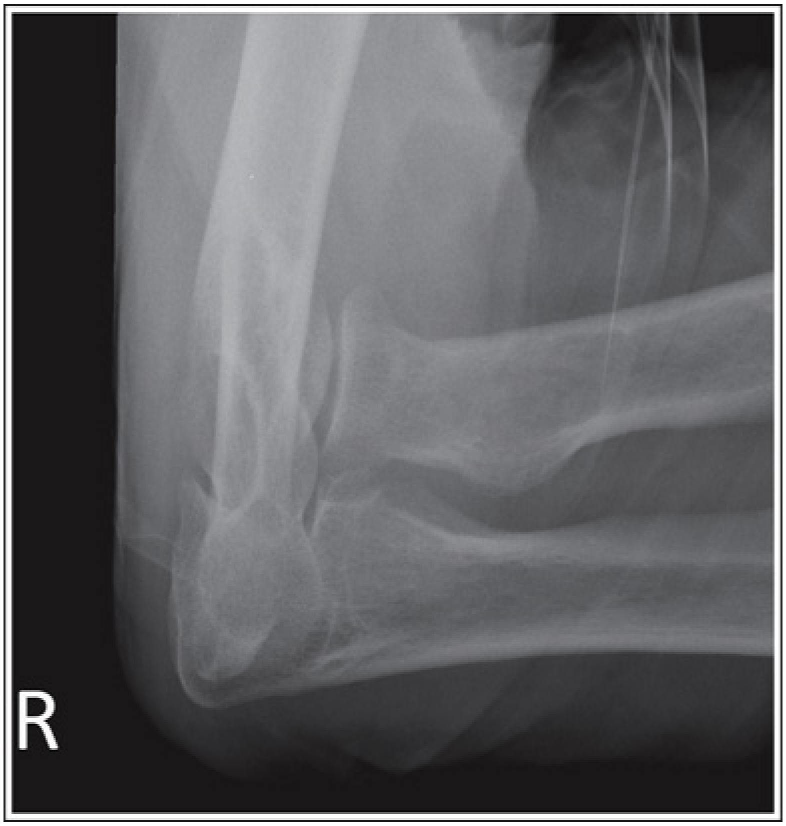


FIGURE 4.195 Axiolateral elbow projection (Coyle method) taken with the wrist in a PA projection and demonstrating the radial tuberosity and medial and lateral aspects of the radial head in profile.

Wrist Positioning: Radial Head Visualization

As with the lateral elbow projection, the position of the wrist determines which surfaces of the radial head are placed in profile, but it is different than discussed for the lateral elbow projection because of the 45-degree CR angle that is used for the axiolateral projection.

- *Wrist is in a lateral projection.* The radial tuberosity is not demonstrated in profile but is superimposed by the radius. In this position, the anterior aspect of the radial head is demonstrated in

profile on the anterior arm surface and the posterior aspect of the radial head is demonstrated in profile on the posterior arm surface (see Figs. **4.192**–**4.194**).

- *Wrist is in a PA projection.* The radial tuberosity and medial aspect of the radial head are demonstrated in profile on the posterior arm surface and the lateral aspect of the radial head appears in profile on the anterior arm surface (**Fig. 4.195**).

Axiolateral Elbow (Coyle Method) Analysis Practice

IMAGE 4.46

Analysis

The capitulum-radius joint space is closed, the radial head is demonstrated distal to the coronoid process, and the capitulum is demonstrated too far anterior to the medial trochlea. The distal forearm was depressed. The radial head is superimposed over more than just the tip of the coronoid process, and the medial trochlea and capitulum demonstrate slight superimposition. The proximal humerus was elevated. The lateral and medial surfaces of the radial head are in profile. The wrist was placed in a PA projection.

Correction

Elevate the distal forearm and depress the proximal humerus until the humeral epicondyles are aligned perpendicular to the IR.

IMAGE 4.47

Analysis

The radial head is superimposed over more than just the tip of the coronoid process, and the medial trochlea and capitulum demonstrate slight superimposition. The proximal humerus was elevated. The radial head is demonstrated proximal to the coronoid process and the capitulum is demonstrated too far posterior to the medial trochlea. The distal forearm was elevated. The anterior and posterior surfaces of the radial head are demonstrated. The wrist was placed in a lateral projection.

Correction

Depress the proximal humerus and the distal forearm until the humeral epicondyles are aligned perpendicular to the IR.

Humerus: AP Projection

See **Table 4.22** and Figs. **4.196–4.198**.

External Humerus Rotation

When the humeral epicondyles and the greater tuberosity are not demonstrated in profile, measure the amount of radial head superimposition on the ulna to determine how the patient should be repositioned. If less than one-eighth of the radial head superimposes the ulna, the humerus has been externally rotated more than needed to obtain an AP projection (**Fig. 4.199**).

Internal Humerus Rotation

If more than one-eighth of the radial head superimposes the ulna and the greater tubercle is not in profile laterally, the humerus has not been externally rotated enough to bring the humeral epicondyles parallel with the IR (**Fig. 4.200**).

Positioning for Humeral Fracture

When a fracture of the humerus is suspected or a follow-up projection is being taken to assess healing of a humeral fracture, the arm should not be externally rotated to obtain the AP projection, unless specified by your facility, because external rotation of the arm may increase the risk of nerve damage. For such an examination, the joint closer to the fracture should be aligned in the true AP projection.

TABLE 4.22

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

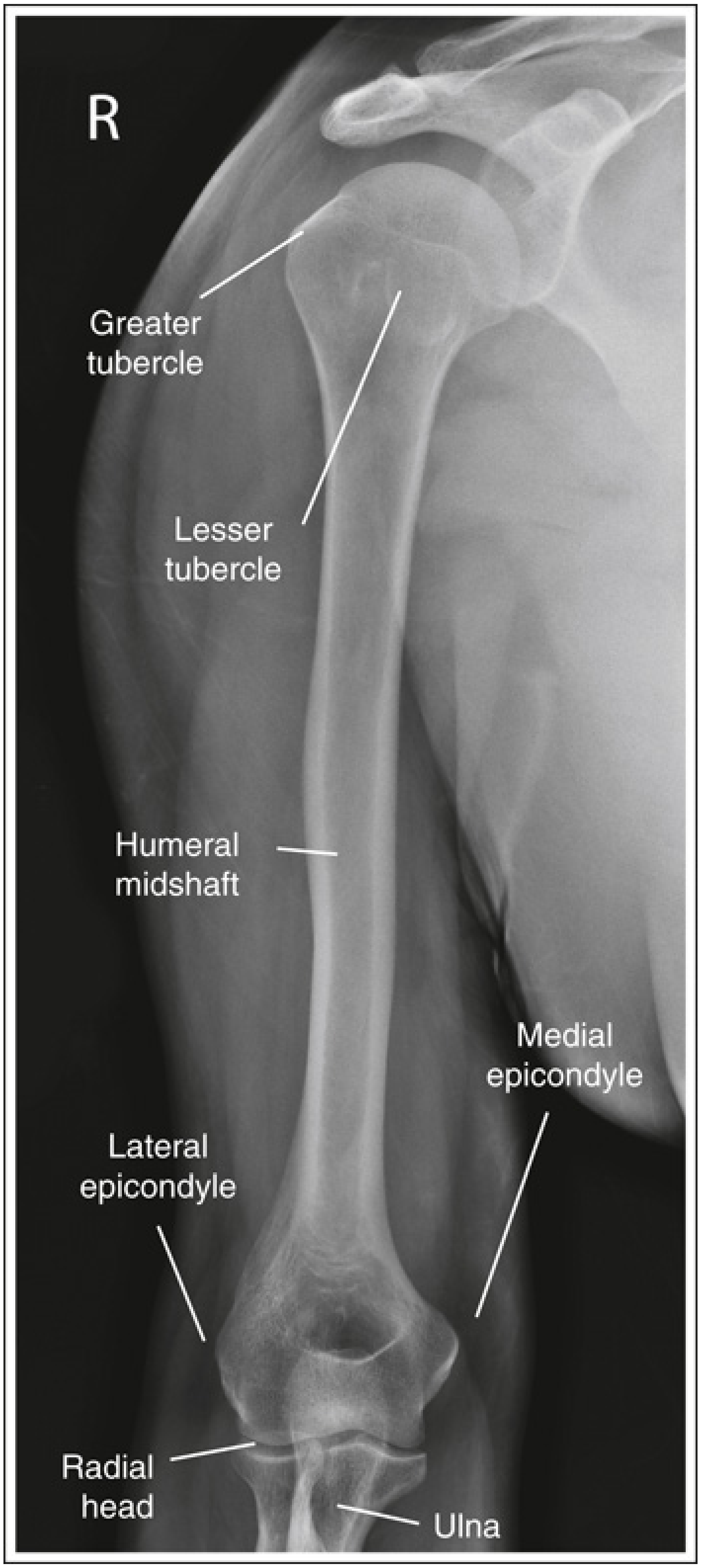

R
Greater tubercle
Lesser tubercle
Humeral midshaft
Medial epicondyle
Lateral epicondyle
Radial head
Ulna

FIGURE 4.196 AP humerus projection with accurate positioning.

- *If the fracture site is situated closer to the shoulder joint* and the arm cannot be externally rotated, the greater tuberosity is placed in profile by rotating the body toward the affected humerus 35 to 40 degrees (**Fig. 4.201**). Depending on the amount of humeral rotation at the fracture site, the proximal and the distal humerus may or may not be an AP projection at the same time (**Fig. 4.202**).
- *If the fracture is situated closer to the elbow joint*, extend the arm and rotate the torso toward the affected humerus until the humeral epicondyles are aligned parallel with the IR. Depending on the amount of humeral rotation at the fracture site, the greater tubercle may or may not be in profile (**Fig. 4.203**).

Field Size and Collimation

The collimated field should extend at least 1 inch (2.5 cm) beyond each joint space to ensure that the joints are included in the exposure field. The elbow is located approximately 0.75 inch (2 cm) distal to the medial epicondyle. The shoulder joint is located at the same level as the palpable coracoid. For a patient with a long humerus, it may be necessary to position the humerus somewhat diagonally on the IR to obtain the needed IR length. The collimator head can be rotated to align the long axis of the collimated light field with the long axis of the humerus to allow for tight collimation.

FIGURE 4.197 Pediatric AP humerus projection with accurate positioning.

FIGURE 4.198 Proper patient positioning for AP humerus projection. The collimator head is rotated to attain tighter collimation.

FIGURE 4.199 AP humerus projection taken with the arm externally rotated.

FIGURE 4.200 AP humerus projection taken with the arm internally rotated to align humeral epicondyles parallel with IR.

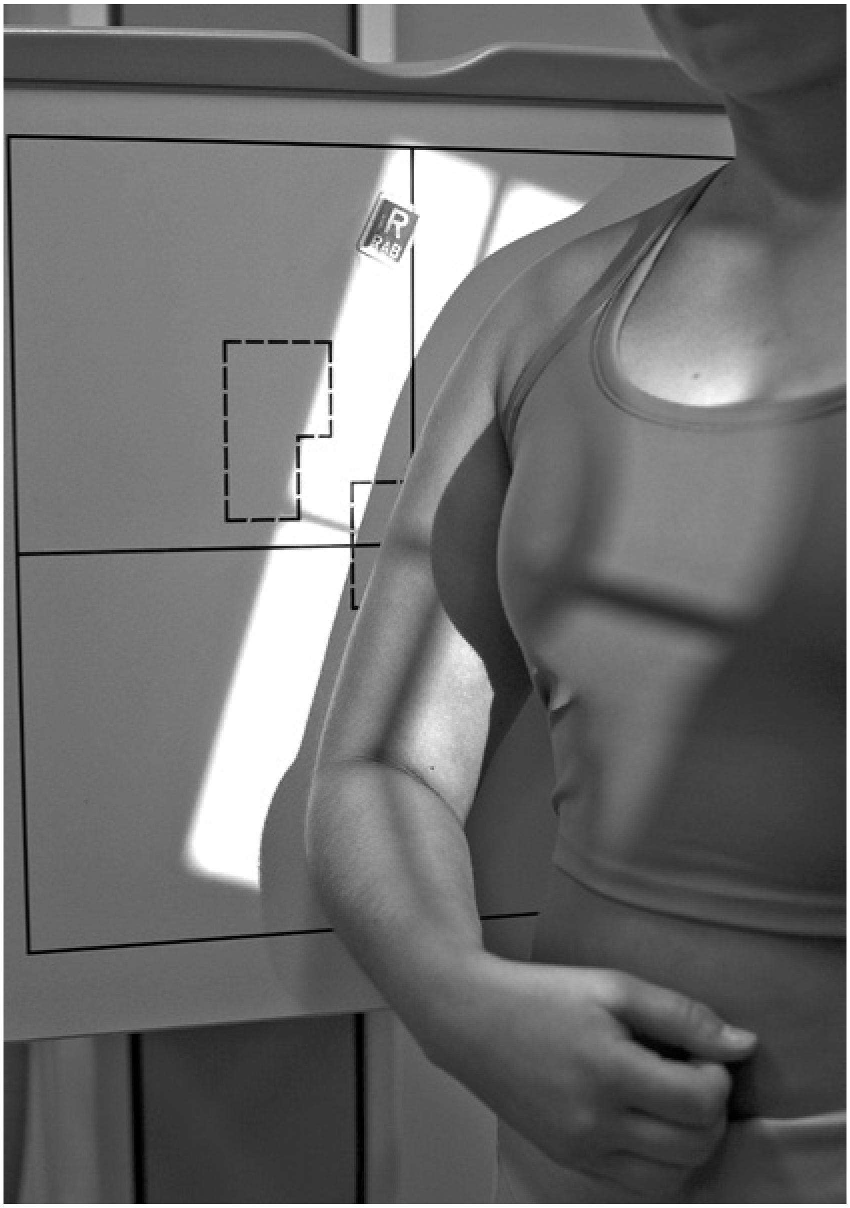


FIGURE 4.201 Patient positioning for AP humerus projection when fracture is located close to shoulder.

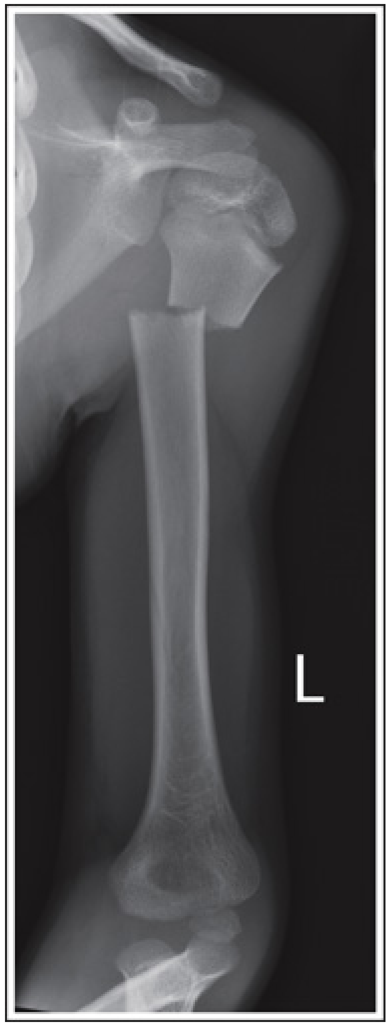


FIGURE 4.202 AP humerus projection demonstrating a fractured humerus.

FIGURE 4.203 AP humerus projection demonstrating a distal humerus fracture.

AP Humerus Analysis Practice

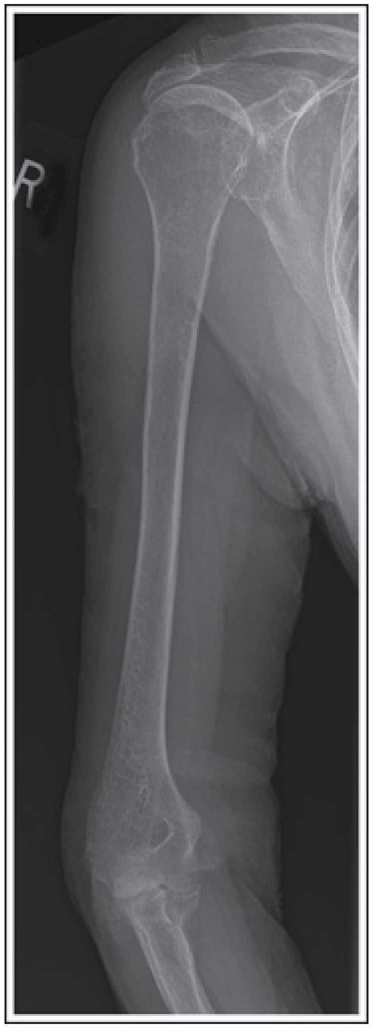


IMAGE 4.48

Analysis

More than one-eighth of the radial head superimposes the ulna and the greater tubercle is not in profile laterally. The humerus was not externally rotated enough to place the humeral epicondyles parallel with the IR.

Correction

Externally rotate the humerus until the humeral epicondyles are aligned parallel with the IR.

Humerus: Lateral Projection (Lateromedial and Mediolateral)

See **Table 4.23** and Figs. **4.204–4.207**.

Mediolateral Projection: Torso in PA Projection

The mediolateral projection positions the torso in an upright PA projection, with the arm internally rotated until the humeral epicondyles are perpendicular to the IR (see **Fig. 4.206**). In this projection it is important that the torso maintains a PA projection. Do not allow the patient to rotate the torso toward the affected humerus as such torso obliquity causes an increase in tissue thickness at the proximal humerus compared with the distal humerus, resulting in higher brightness and lower contrast resolution in this area (**Fig. 4.208**).

Lateromedial Projection: Insufficient Internal Arm Rotation

For the lateromedial humerus projection the torso is in an AP projection, with the arm internally rotated until the humeral epicondyles are perpendicular to the IR (see **Fig. 4.207**). If the forearm is positioned across the body in an attempt to flex the elbow and the arm is not internally rotated enough to bring the distal humerus away from the IR to position the humeral epicondyles perpendicular to the IR (**Fig. 4.209**), the projection demonstrates the capitulum posterior to the medial trochlea, a distorted proximal forearm, and the lesser tubercle in partial profile (**Fig. 4.210**).

Mediolateral Versus Lateromedial Projection

For a lateral humerus projection, the CR is centered to the midhumeral shaft, which is located approximately 5 inches (13 cm) from the elbow joint. Because the elbow joint is placed so far away from the CR, diverged

x-ray beams are used to image the elbow joint. This causes the anatomic structures positioned farthest from the IR to be diverged more distally than the anatomic structures positioned closest to the IR. In the mediolateral projection, the medial trochlea is placed farther from the IR than the capitulum. Consequently x-ray beam divergence will project the medial trochlea distal to the capitulum. In the lateromedial projection the capitulum is situated farther from the IR; therefore the x-ray beam divergence will project it distally to the medial trochlea.

Positioning for Humeral Fracture

When a fracture of the humerus is suspected or a follow-up projection is being taken to assess healing of a fracture, the forearm or humerus should not be rotated to obtain a lateral projection unless indicated by your facility. Rotation of the forearm and humerus may increase the risk of radial nerve damage and displacement of the fracture fragments space (**Fig. 4.211**). Because the humerus should not be rotated for a trauma examination, a lateral projection of the proximal and distal humerus may need to be obtained by positioning the patient differently.

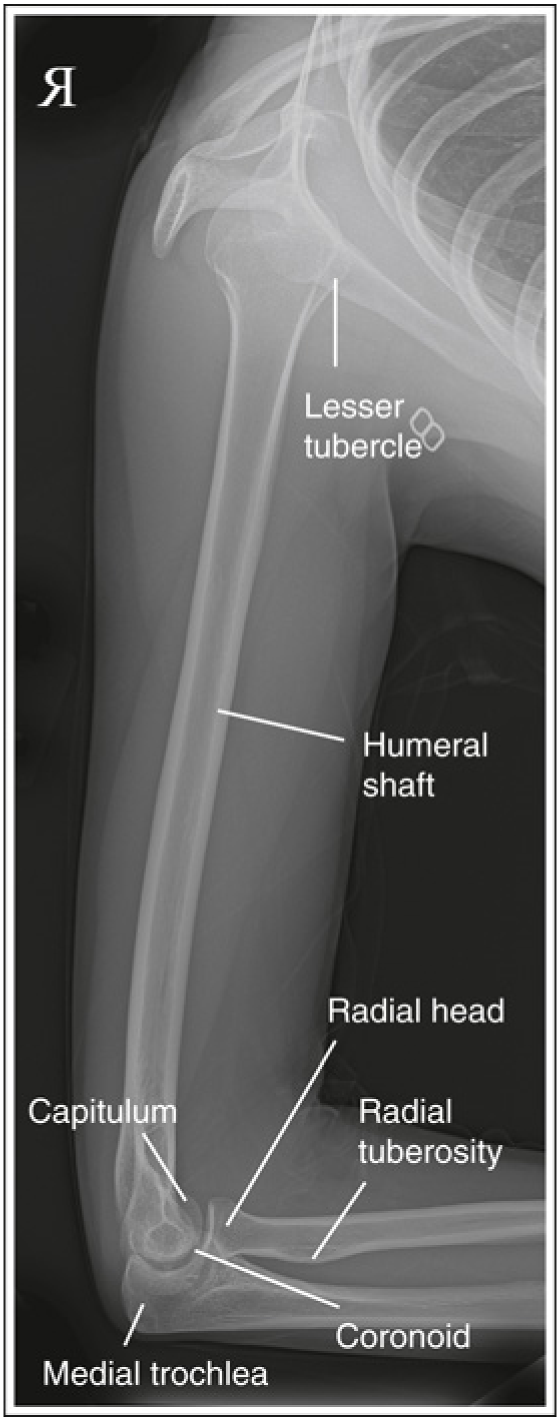


FIGURE 4.204 Mediolateral humerus projection with accurate positioning.

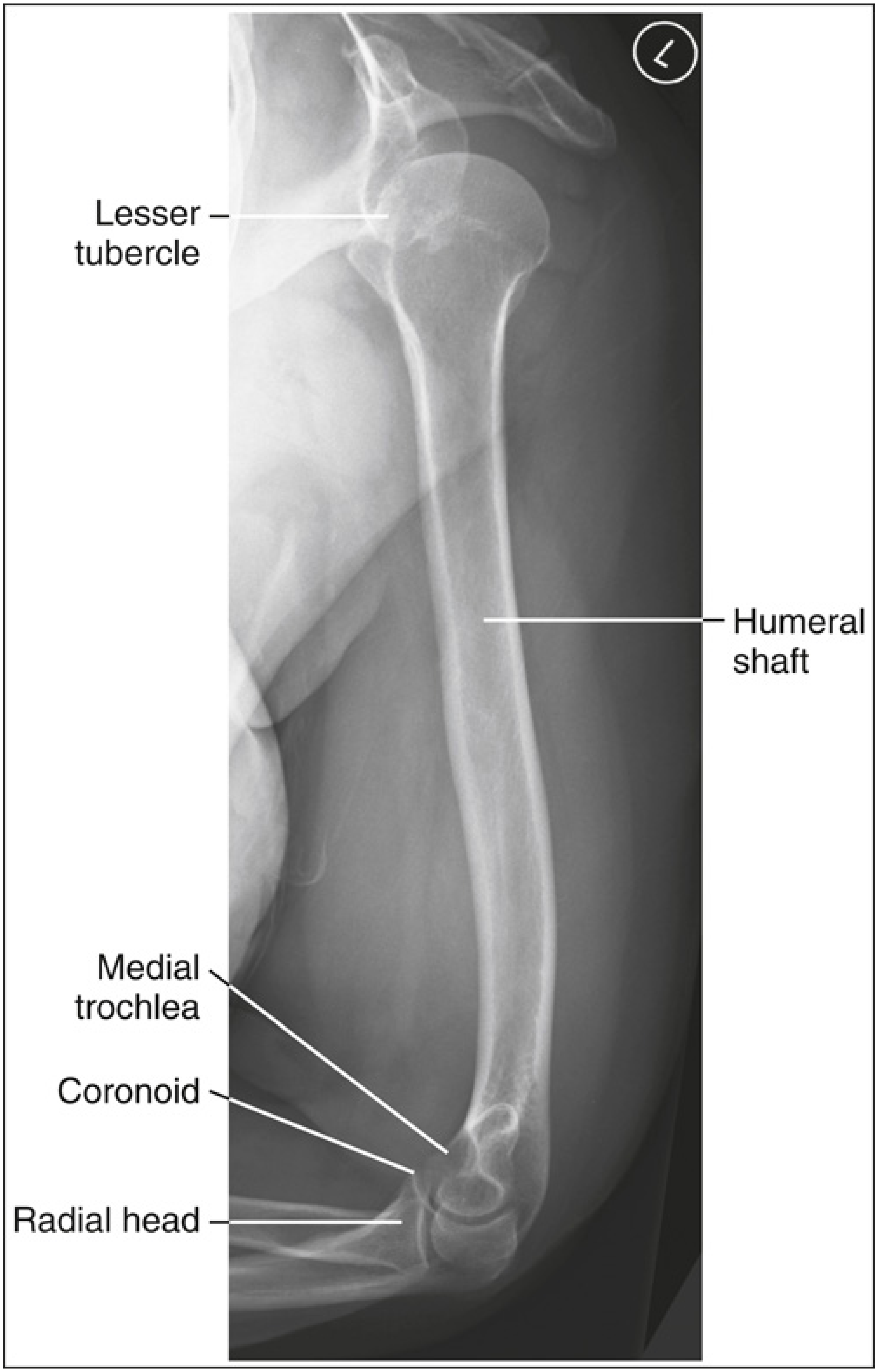

L
Lesser tubercle
Humeral shaft
Medial trochlea
Coronoid
Radial head

FIGURE 4.205 Lateromedial humerus projection with accurate positioning.

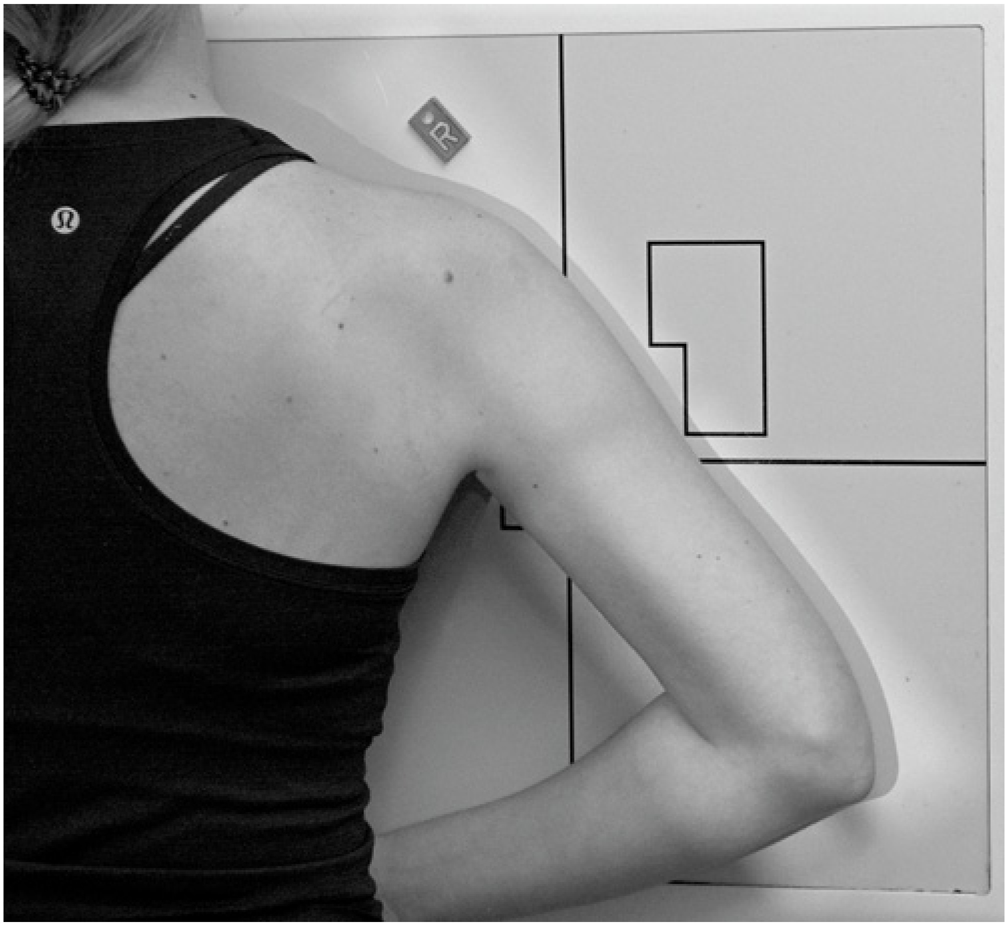


FIGURE 4.206 Proper patient positioning for mediolateral humerus projection.

FIGURE 4.207 Proper patient positioning for lateromedial humerus projection.

FIGURE 4.208 Mediolateral humerus projection taken with the torso rotated toward the humerus, increasing the tissue thickness at the proximal humerus.

FIGURE 4.209 Patient positioned for lateromedial humerus projection with poor distal humerus alignment.

FIGURE 4.210 Lateromedial humerus projection taken with insufficient internal rotation to position the humeral epicondyles perpendicular to the IR.

TABLE 4.23

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor; *PA*, posteroanterior.

Positioning for Distal Humeral Fracture

Obtain a lateral distal humerus projection by gently sliding an IR between the patient and the distal humerus. Adjust the IR until the epicondyles are positioned perpendicularly to the IR. Place a flat contact protecting shield between the patient and the IR to absorb any radiation that would penetrate the IR and expose the patient. Finally center the CR perpendicularly to the IR and distal humerus (**Fig. 4.212**). This positioning should demonstrate a lateral projection of the distal humerus with superimposition of the epicondyles and of the radial head and coronoid process (**Fig. 4.213**).

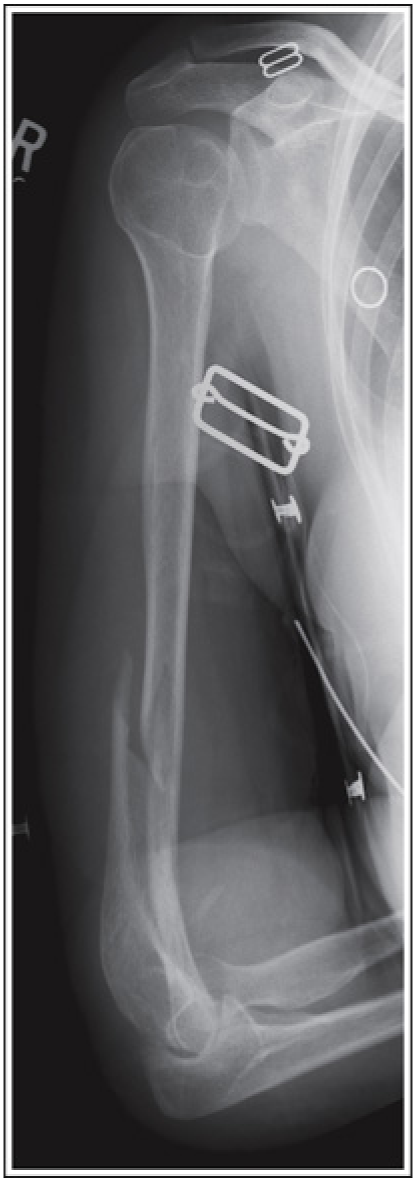


FIGURE 4.211 Lateral humerus projection demonstrating a fractured distal humerus.

FIGURE 4.212 Proper patient positioning for distal humerus fracture.

FIGURE 4.213 Lateral distal humerus projection demonstrating a fractured distal humerus.

FIGURE 4.214 Proper PA oblique projection (scapular Y method) positioning of patient for proximal humerus fracture.

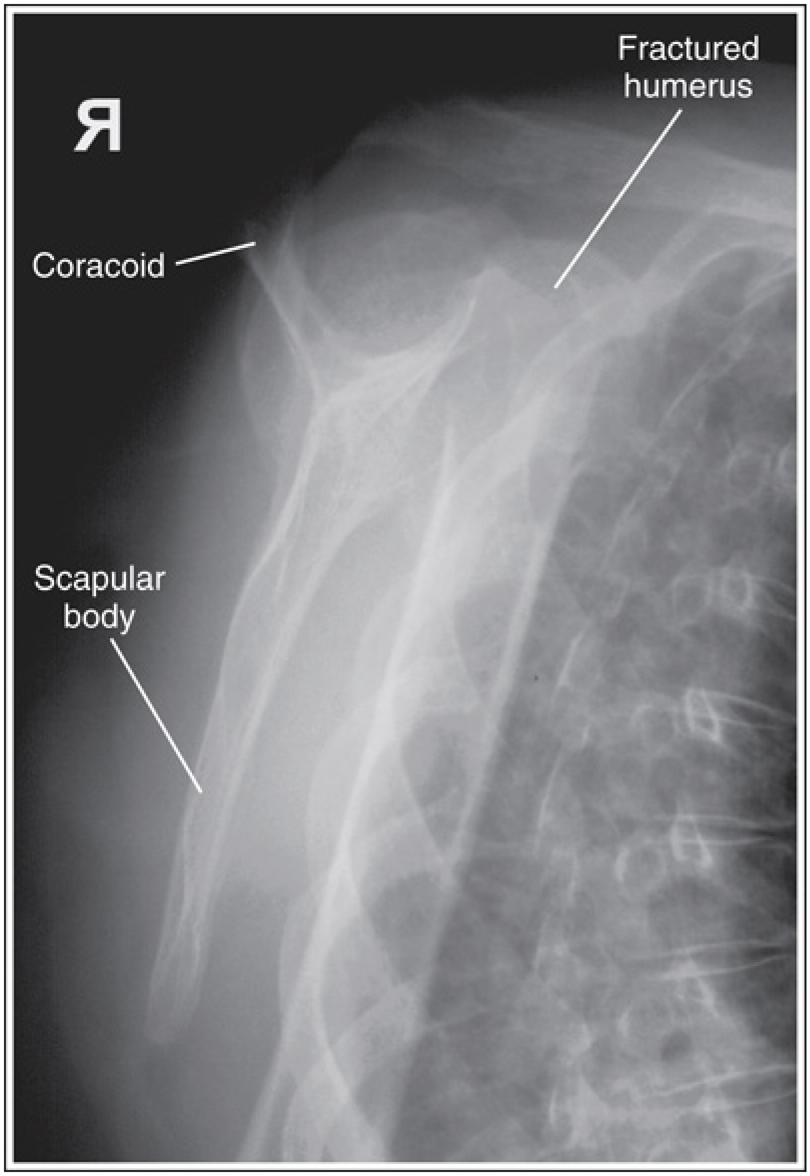


FIGURE 4.215 Accurately positioned AP oblique (Scapular Y method) shoulder projection demonstrating a fractured proximal humerus.

Proximal Humeral Fracture

A lateral proximal humeral fracture can be demonstrated by obtaining one of the following projections.

- *The scapular Y, PA axial projection* (Figs. **4.214** and **4.215**). Precise positioning and evaluating points for this projection can be studied by referring to the discussion of the scapular Y, PA axial projection in **Chapter 5**.
- *The transthoracic lateral projection* (Figs. **4.216** and **4.217**).

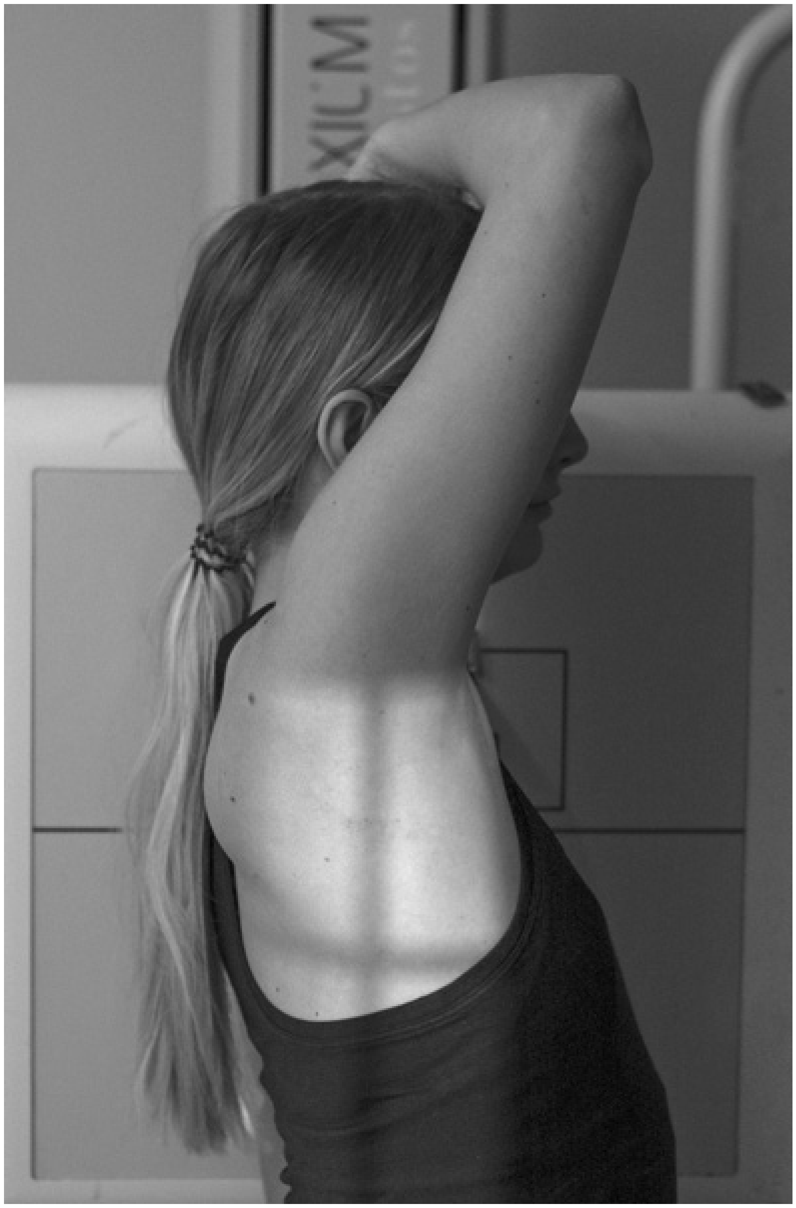


FIGURE 4.216 Proper transthoracic lateral positioning of patient for proximal humerus fracture.

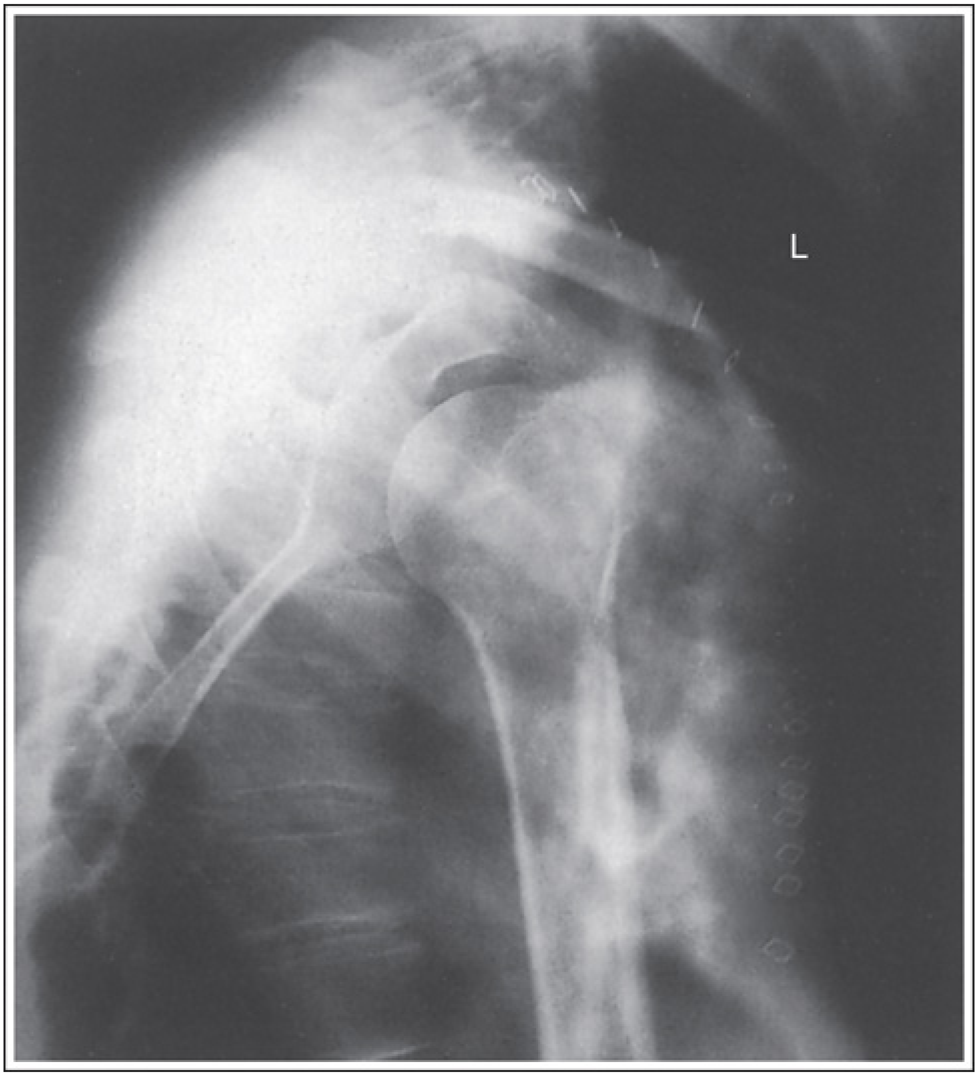


FIGURE 4.217 Transthoracic lateral proximal humerus projection with accurate positioning.

Lateral Humeral Analysis Practice

IMAGE 4.49 Mediolateral projection.

Analysis

There is poor contrast resolution between the proximal and distal humerus, because the torso was rotated toward the humerus instead of staying in a PA projection. A proximal humerus fracture is present.

Correction

When a fracture is suspected the arm should not be rotated to obtain a lateral humerus projection; instead the alternate PA oblique (scapular Y) or transthoracic lateral projection should be obtained.

IMAGE 4.50 Lateromedial projection.

Analysis

The capitulum is posterior to the medial trochlea, the proximal forearm is distorted, and the lesser tubercle is in only partial profile. The arm was not internally rotated enough to position the humeral epicondyles perpendicular to the IR.

Correction

If the distal forearm is situated on the abdomen, rest it on the IR. Internally rotate the arm until the humeral epicondyles are positioned perpendicular to the IR.

Chapter 5: Image Analysis of the Shoulder

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Identify the required anatomy on shoulder, clavicular, acromioclavicular (AC) joint, and scapular projections.
- Describe how to properly position the patient, image receptor (IR), and central ray (CR) for projections of the shoulder, clavicle, AC joint, and scapula.
- List the image analysis guidelines and the related positioning procedure for projections of the shoulder, clavicle, AC joint, and scapula.
- State how to properly reposition the patient when shoulder, clavicular, AC joint, and scapular projections show poor positioning.
- State the technical factors routinely used for shoulder, clavicular, AC joint, and scapular projections and describe which anatomic

structures are visible when the correct technique factors are used.

- State where the humerus is positioned if a shoulder dislocation is demonstrated on the AP and PA oblique (scapular Y) shoulder projections.
- Discuss how the visualization of the proximal humerus changes as the humeral epicondyles are placed at different angles to the IR.
- Explain how the scapula moves when the humerus is abducted.
- List the anatomic structures that form the Y on a PA oblique (scapular Y) shoulder projection.
- State how the lateral and medial borders of the scapula can be identified.
- Discuss why non–weight-bearing and weight-bearing projections are required when AC joints are imaged.
- Describe how the shoulder is retracted to obtain an AP projection of the scapula.
- Discuss which anatomic structures must move to allow the humerus to abduct.
- Describe the effect of humeral abduction on the degree of patient obliquity needed to position the scapula in a lateral projection.

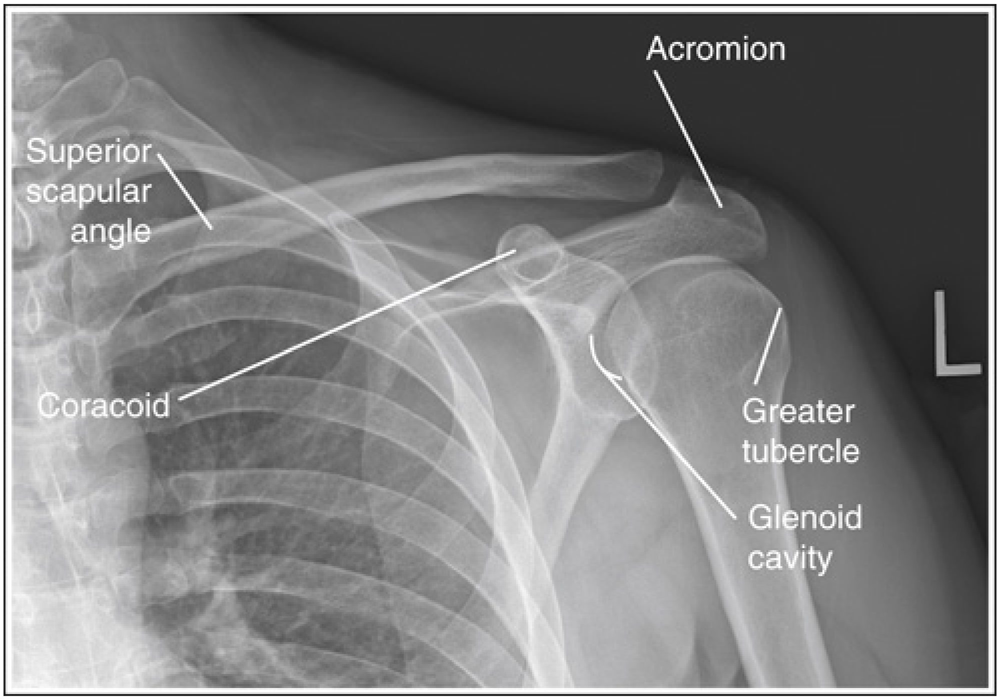


FIGURE 5.1 Upright AP shoulder projection with accurate positioning.

TABLE 5.1

AC, Acromioclavicular; *AEC*, automatic exposure control; *AP*, anteroposterior; *PA*, posteroanterior; *SID*, source–image receptor distance.

TABLE 5.2

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

Box 5.1 Shoulder Guidelines

VOI, Values of interest.

- The facility's identification requirements are visible.

- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomical structures are sharply defined.
- Contrast resolution is adequate to demonstrate the surrounding soft tissue, bony trabecular patterns, and cortical outlines.
- No quantum mottle or saturation is present.
- Scatter radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

KEY TERMS

abduct anterior shoulder dislocation bilateral Hill-Sachs defect longitudinal foreshortening protract recumbent retract supraspinatus outlet transverse foreshortening unilateral weight-bearing

Image Analysis Guidelines

Technical Data

See **Table 5.1** and **Box 5.1**.

Shoulder: AP Projection

See **Table 5.2** and Figs. **5.1** and **5.2**.

Supine Versus Upright

The anteroposterior (AP) projection of the shoulder positions the scapular body at 35 to 45 degrees of obliquity, with the lateral scapula situated more anteriorly than the medial scapula. This positioning causes the scapular body to demonstrate transverse foreshortening and the glenoid cavity to be partially visible on an AP projection. The exact amount of scapular foreshortening and glenoid cavity that is demonstrated is affected by the degree of shoulder retraction. When the projection is obtained in a supine position there is greater shoulder retraction in comparison to when the shoulder is obtained in an upright position because of the gravitation pull placed on the shoulder and the degree of forced thoracic spinal straightening that occurs as the patient lies on the firm imaging table. The supine method causes increased shoulder retraction and the scapular body to be positioned more nearly parallel with the image receptor (IR), demonstrating decreased transverse foreshortening of the scapular body and glenoid cavity visualization.

Torso Rotated Toward Affected Shoulder

When the torso is rotated toward the affected shoulder the resulting projection demonstrates the medial clavicular end rotated away from the lateral edge of the vertebral column, increased thoracic and scapular body superimposition, increased clavicular foreshortening, and decreased glenoid cavity visualization (**Fig. 5.3**).

Torso Rotated Away From Affected Shoulder

When the torso is rotated away from the affected shoulder the resulting projection demonstrates the medial clavicular end superimposing the vertebral column, decreased thoracic and scapular body superimposition, decreased clavicular foreshortening, and increased glenoid cavity visualization (**Fig. 5.4**).

Upper Midcoronal Plane Tilted Anteriorly

If the upper midcoronal plane is tilted anteriorly, the scapular body will demonstrate longitudinal foreshortening, and the superior scapular angle will be shown superior to the midclavicle on the projection (**Figs. 5.5** and **5.6**).

Upper Midcoronal Plane Tilted Posteriorly

If the upper midcoronal plane is tilted posteriorly, the scapular body will demonstrate longitudinal foreshortening and the superior scapular angle will be shown inferior to the midclavicle in the projection (**Fig. 5.7**).

Kyphotic Patient

The kyphotic patient's increase in spinal convexity prevents the upper midcoronal plane from being straightened and positioned parallel with the IR, and situates the scapula more anteriorly as in maximum shoulder protraction. As a result, AP shoulder projections obtained with the kyphotic patient positioned as close to the routine for the projection as the patient can accommodate will demonstrate the superior scapular angle superior to the midclavicle, longitudinal scapular foreshortening, increased transverse scapular foreshortening, and increased glenoid cavity visualization. **Fig. 5.8** demonstrates an AP shoulder obtained on a nonkyphotic and kyphotic patient for comparison.

There are alternative positioning methods to better demonstrate the scapular body with minimal foreshortening for the kyphotic patient. One method keeps the midcoronal plane parallel with the IR and uses a cephalic central ray (CR) angulation to offset the longitudinal foreshortening. With this method, the CR is angled until it is perpendicular with the scapular body. Because the IR is not perpendicular to the CR for this method, there

will be elongation that will increase as the CR to IR angle becomes more acute. The second method is to lean the shoulders and upper thoracic vertebrae posteriorly to place the upper midcoronal plane at an angle with the IR that brings the scapular body parallel with the IR and use a horizontal CR. The kyphotic patient will also be unable to retract the shoulder to decrease the transverse scapular foreshortening that is caused by the condition, though they can be rotated toward the affected shoulder to decrease it.

External Humerus Rotation

If the humerus is externally rotated more than needed to obtain a neutral rotation, the resulting projection will demonstrate the greater tubercle in profile laterally and the humeral head in profile medially (**Figs. 5.9** and **5.10**).

Internal Humerus Rotation

If the humerus is internally rotated, the resulting projection demonstrates the lesser tubercle in profile medially, and the humeral head and greater tubercle will be superimposed (**Figs. 5.11** and **5.12**). Internal humeral rotation also causes shoulder protraction, which moves the lateral scapular border anteriorly, increasing the degree of transverse scapular body foreshortening and the amount of the glenoid cavity demonstrated.

Identifying the Location of the Tubercles When Positioning

The position of the humeral epicondyles with respect to the IR determines whether the greater tubercle and humeral head or the lesser tubercle will be in partial or full profile on an AP shoulder projection. The technologist can ensure they have the tubercle and humeral head positioned accurately before they expose the projection by understanding how the humeral

epicondyles align with the proximal humerus. The palpable lateral epicondyle is aligned with the greater tubercle, and the palpable medial epicondyle is aligned with the humeral head. This means that when the humeral epicondyles are palpated and positioned so they are aligned parallel with the IR, the AP shoulder projection demonstrates the greater tubercle in profile laterally and humeral head in profile medially (see **Figs. 5.9** and **5.10**). The lesser tubercle is anteriorly located at right angles to the greater tubercle and humeral head. To position the lesser tubercle in profile, the anterior aspect of the proximal humerus must be in profile and is accomplished by aligning the humeral epicondyles perpendicular to the IR (see **Figs. 5.11** and **5.12**).

AP Shoulder Projections Taken to Demonstrate Lesser and Greater Tubercles

AP shoulder projections obtained to demonstrate the lesser and greater tubercles may be specifically requested. These projections are completed as described in **Table 5.2** (see **Figs. 5.9** and **5.11**) and should demonstrate the greater or lesser tubercle, respectively, if accurately positioned (see **Figs. 5.10** and **5.11**).

Excessive External Rotation

When obtaining the externally rotated projection to demonstrate the greater tubercle in profile, only externally rotate the humerus until the epicondyles are parallel with the IR, even if the patient can externally rotate the humerus more (**Fig. 5.13**).

Proximal Humeral Fractures

The acceptable AP proximal humeral projection that demonstrates a fracture will have varying lesser and greater tubercle, and glenoid cavity and

humeral head relationships. For example, a proximal humeral head fracture may demonstrate the humeral head shifted away from the glenoid cavity, often not seeming to be associated with the humerus at all, and does not demonstrate either tubercle (**Figs. 5.14** and **5.15**).

Anterior Shoulder Dislocation

This dislocation, which is more common (95%), results in the humeral head being demonstrated anteriorly, beneath the coracoid process (**Figs. 5.16** and **5.17**).

Posterior Shoulder Dislocation

This dislocation, which is uncommon (2% to 4%), results in the humeral head being demonstrated posteriorly, beneath the acromion process or spine of the scapula.

AP Shoulder Analysis Practice

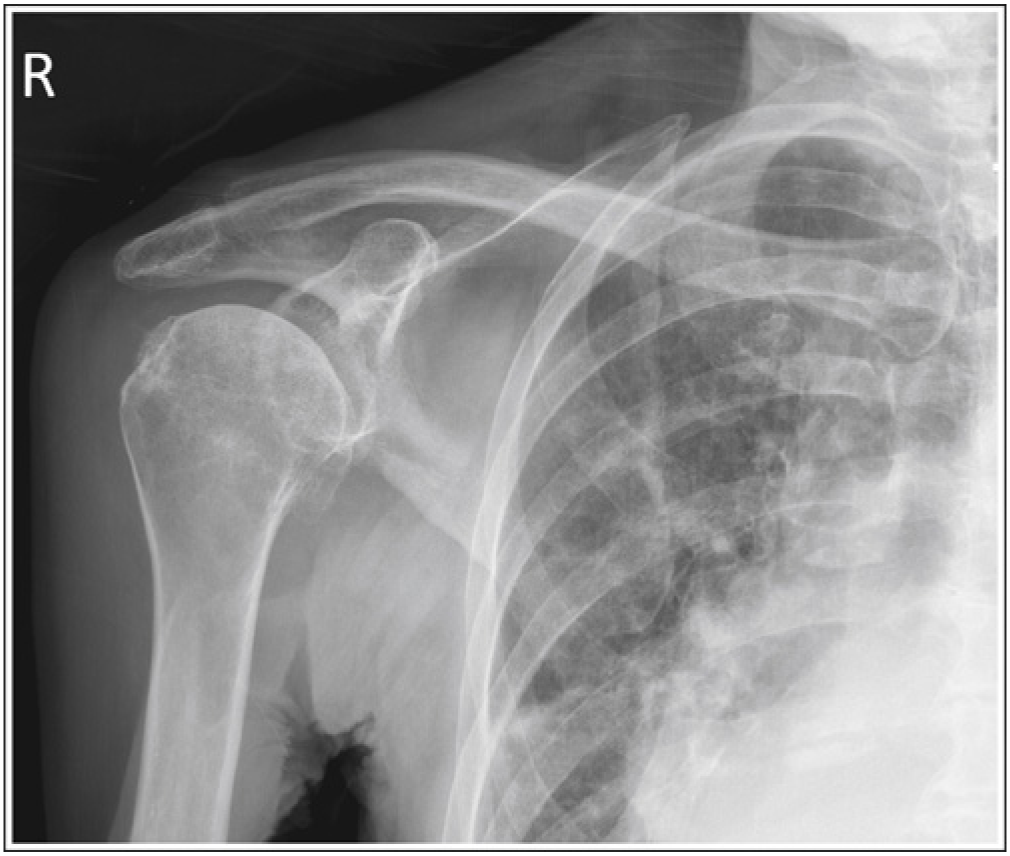


IMAGE 5.1

Analysis

The superior scapular angle is demonstrated superior to the midclavicle. The upper midcoronal plane was tilted anteriorly.

Correction

Straighten the upper midcoronal plane, aligning it parallel with the IR.

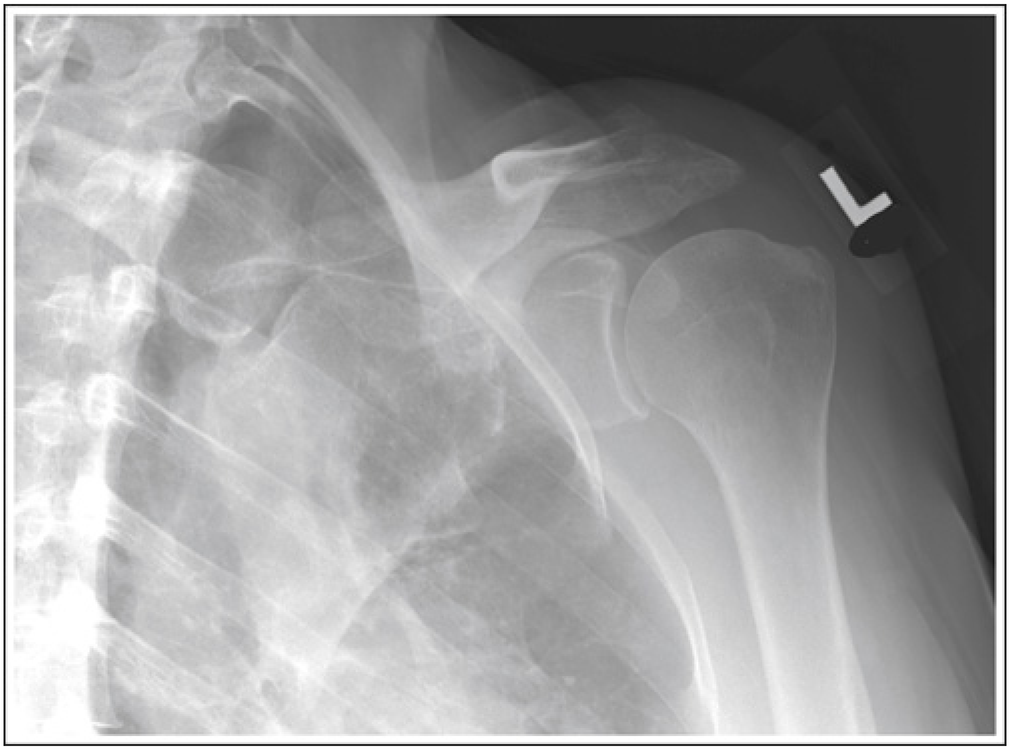


IMAGE 5.2

Analysis

The medial clavicular end is rotated away from the lateral edge of the vertebral column; the glenoid cavity is almost in profile, with only a small amount of the articulating surface demonstrated; the superolateral border of the scapula is superimposed by the thorax; and the clavicle is longitudinally foreshortened. The torso was rotated toward the affected shoulder. The greater tubercle is in profile. If arm rotation remains as is, the greater tubercle will move to partial profile with the rotation problem is fixed.

Correction

Rotate the torso away from the affected shoulder into an AP projection, until the shoulders are positioned at equal distances from the IR, aligning the midcoronal plane parallel with the IR.

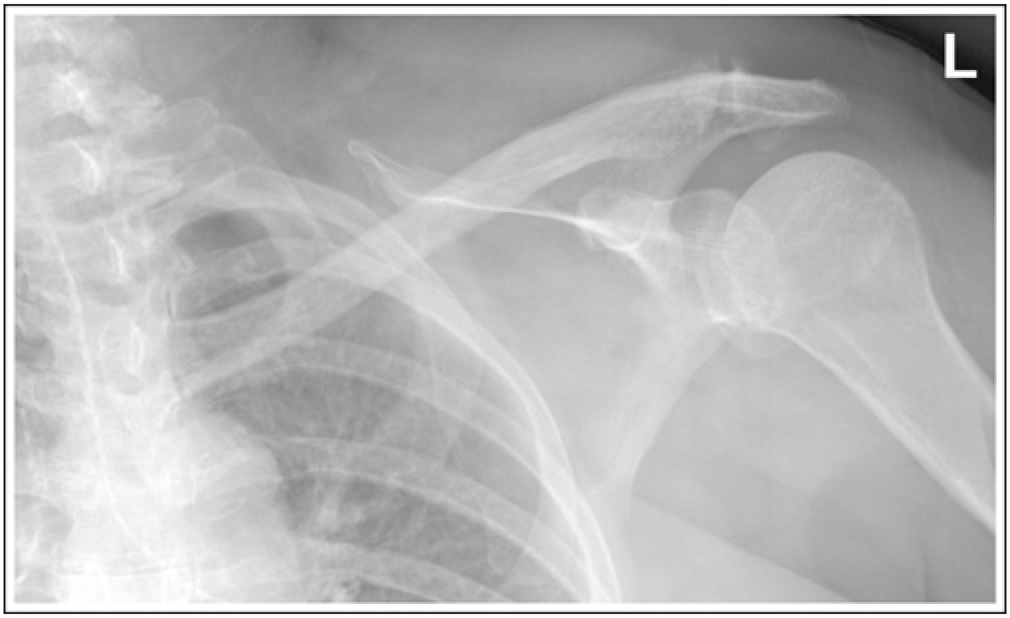


IMAGE 5.3

Analysis

The scapular body is drawn from beneath the thorax and is transversely foreshortened, there is increased glenoid cavity visualization, and the medial clavicular end is superimposed over the vertebral column. The torso was rotated toward the unaffected shoulder. The superior scapular angle is demonstrated superior to the midclavicle. The upper midcoronal plane was tilted anteriorly. The lesser tubercle is in profile. The humeral epicondyles were positioned perpendicular to the IR.

Correction

Rotate the torso toward the affected shoulder into an AP projection, with the shoulders positioned at equal distances from the table; straighten the midcoronal plane, aligning it parallel with the IR; and externally rotate the humeral epicondyles, placing them at a 45-degree angle with the IR.

Shoulder: Inferosuperior Axial Projection (Lawrence Method)

See **Table 5.3** and **Figs. 5.18–5.21**.

TABLE 5.3

CR, Central ray; *IR*, image receptor.

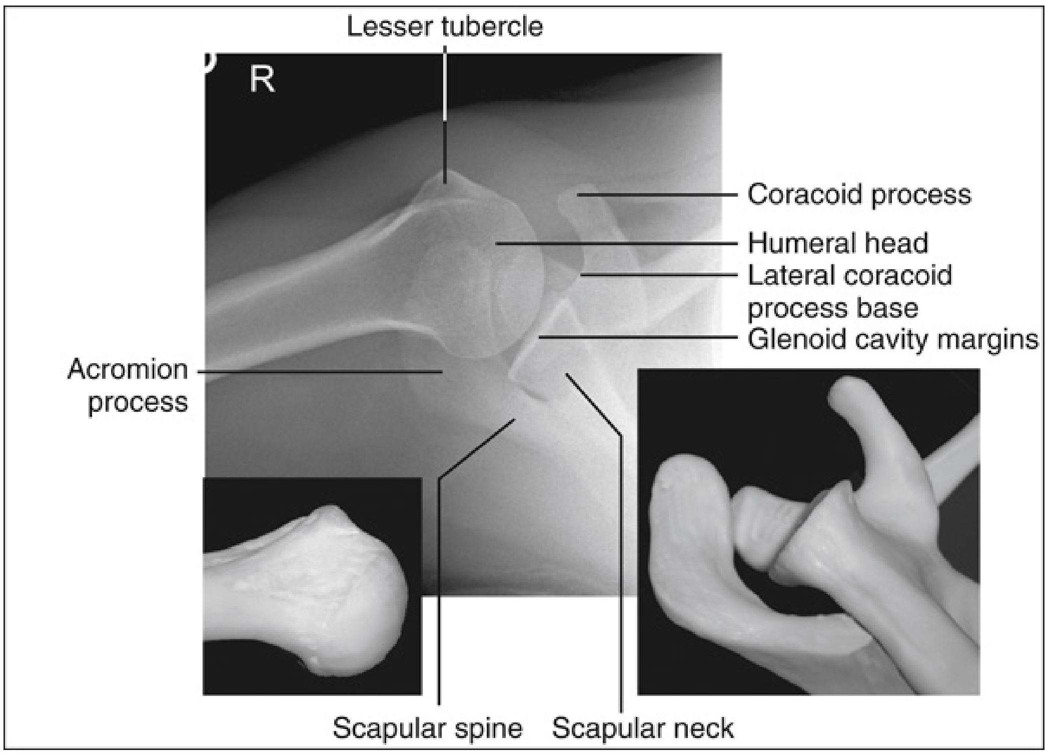


FIGURE 5.18 Inferosuperior axial shoulder projection with accurate positioning obtained with humeral epicondyles positioned parallel with floor.

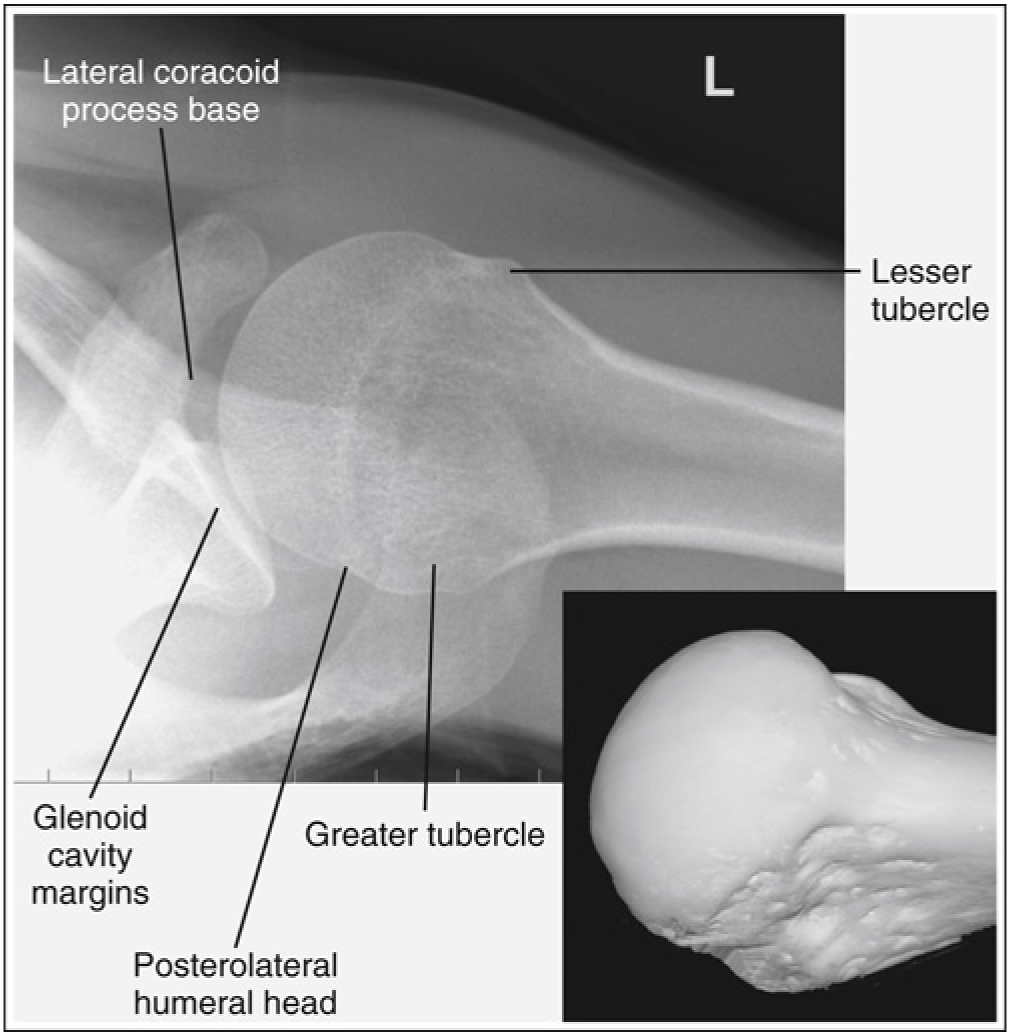


FIGURE 5.19 Inferosuperior axial shoulder projection with accurate positioning obtained with humeral epicondyles positioned at 45 degrees with floor.

FIGURE 5.20 Pediatric inferosuperior axial shoulder projection with accurate positioning.

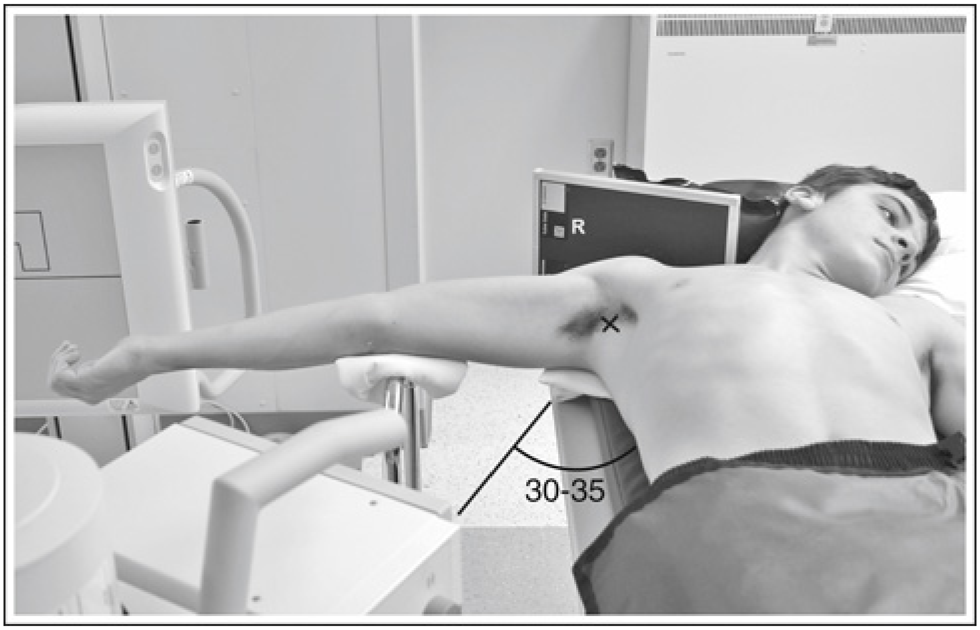


FIGURE 5.21 Proper inferosuperior axial shoulder positioning.

Humeral Abduction and Central Ray Alignment

To obtain an open glenohumeral joint space the CR must be aligned parallel with the joint space and glenoid cavity. Because no palpable structures are present to help align the CR with the glenohumeral joint, rely on degree of humeral abduction to determine scapular movement and alignment. Abduction of the arm is accomplished by combined movements of the glenohumeral joint and the scapula as it glides around the thoracic cavity. The ratio of movement in these two articulations is two parts glenohumeral joint to one part scapulothoracic, with the initial movement (60 degrees of abduction) being primarily glenohumeral joint.

In a patient who is not experiencing severe pain with the 90-degree humeral abduction, the scapular movement angles the glenoid cavity to approximately 30 to 35 degrees with the lateral body surface (see **Figs. 5.21** and **5.22**). Consequently, to align the CR parallel with the glenohumeral

joint on such a patient, the angle between the lateral body surface and CR is 30 to 35 degrees.

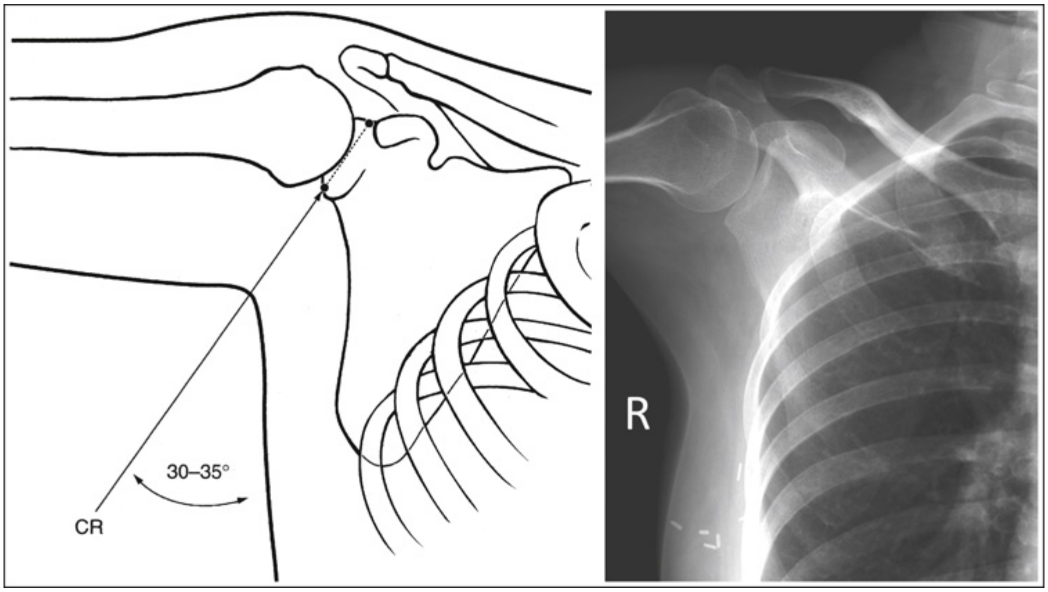


FIGURE 5.22 Placement of glenoid cavity with arm abducted 90 degrees.

Lateral Body Surface to CR Angle Is Too Small

Inaccurate alignment of the CR with the glenohumeral joint space can be identified on a projection by a closed glenohumeral joint space and misalignment of the inferior margin of the glenoid cavity with the lateral edge of the coracoid process base. Because the inferior margin of the glenoid cavity is situated farther from the IR than the coracoid base, it will be projected to one side of the lateral edge of the coracoid process base instead of being aligned with it if the CR is aligned inaccurately. If the CR to lateral body surface angle is too small, the inferior glenoid cavity margin will be projected laterally to the lateral edge of the coracoid process base (**Fig. 5.23**).

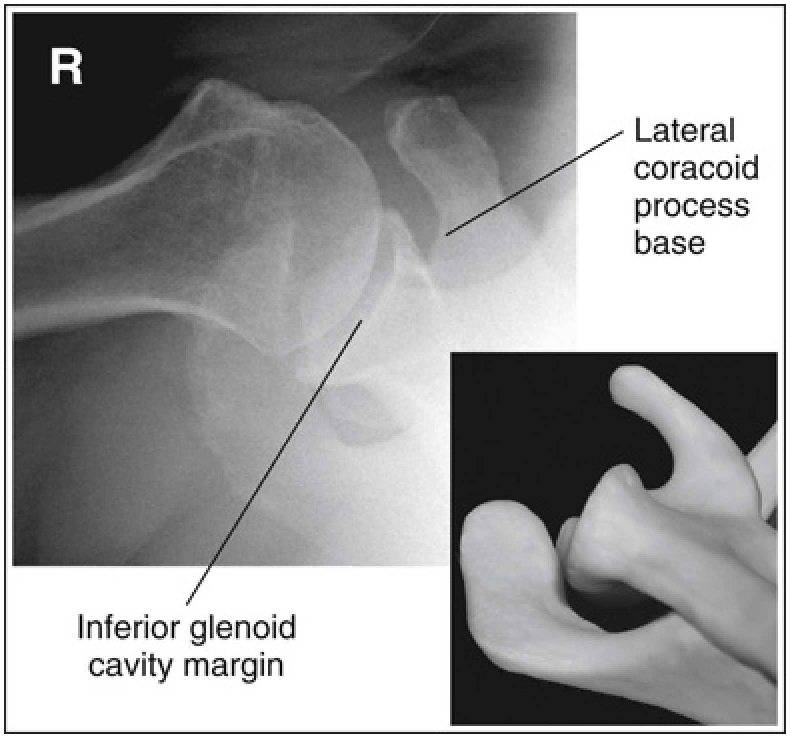


FIGURE 5.23 Inferosuperior axial shoulder projection taken with too small of a CR to lateral body surface angle.

Lateral Body Surface Angle Is Too Large

If the lateral body surface to CR angle is too large, the inferior glenoid cavity margin is projected medially to the lateral edge of the coracoid process base (**Fig. 5.24**).

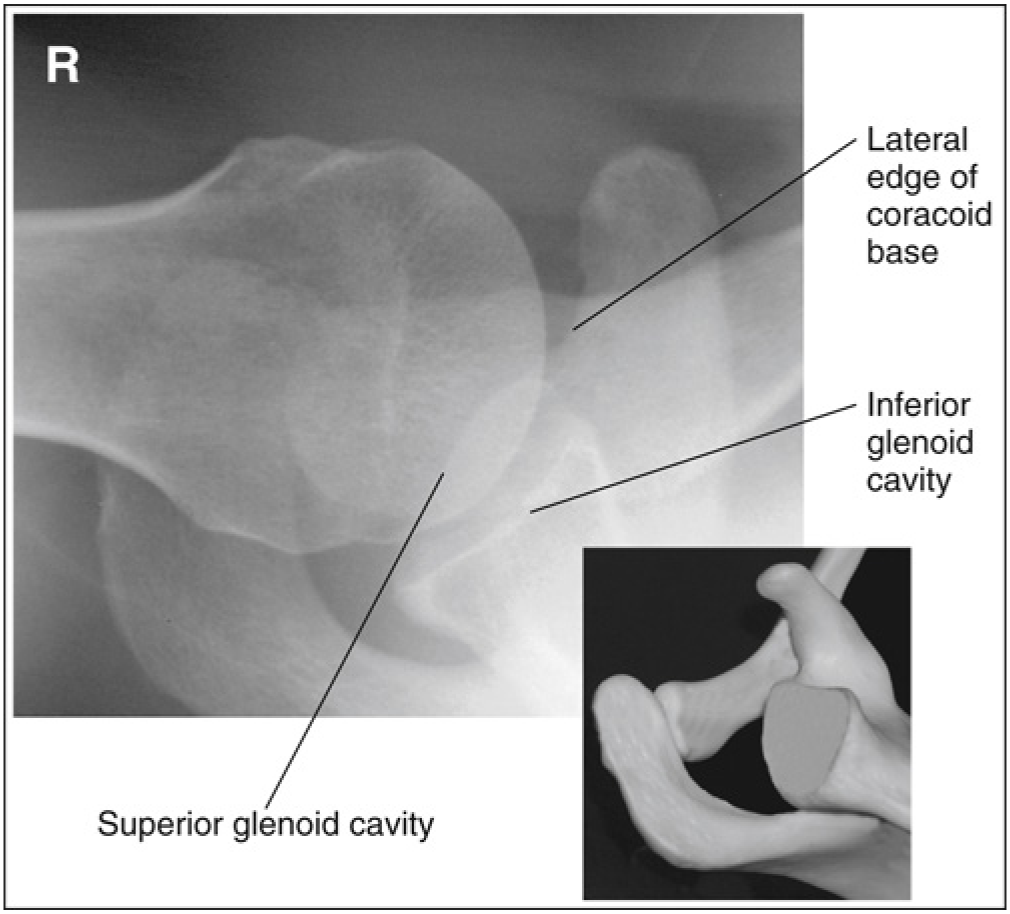


FIGURE 5.24 Inferosuperior axial shoulder projection taken with too large of a CR to lateral body surface angle.

Humeral Fracture or Shoulder Dislocation

If a patient is unable to abduct the arm to the full 90 degrees due to a fracture, shoulder dislocation, or disease process, the angle between the lateral body surface and CR needs to be decreased to align it parallel with the glenohumeral joint and obtain an open space (**Fig. 5.25**). Because the first 60 degrees of humeral abduction involves primarily movement of the glenohumeral joint without accompanying scapulothoracic movement, the angle between the CR and lateral body surface is approximately 20 degrees

when the humerus is abducted up to 60 degrees. As the degree of abduction increases from 60 to 90 degrees, the CR to lateral body surface angle is incrementally increased from 20 to 35 degrees.

It is not advisable to abduct the humerus more than 20 degrees when a fracture or dislocation is suspected to avoid further displacement and nerve damage (**Figs. 5.26** and **5.27**). A lateral of the proximal humerus and the relationships between the humeral head and glenoid cavity can also be demonstrated by performing the PA oblique (scapular Y) projection as described later in the chapter.

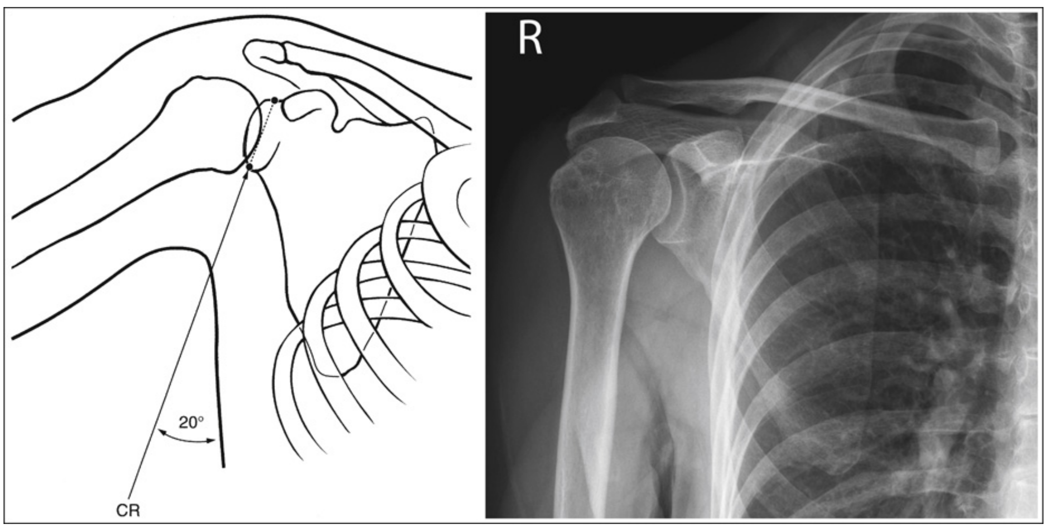


FIGURE 5.25 Placement of glenoid cavity with arm abducted less than 90 degrees.

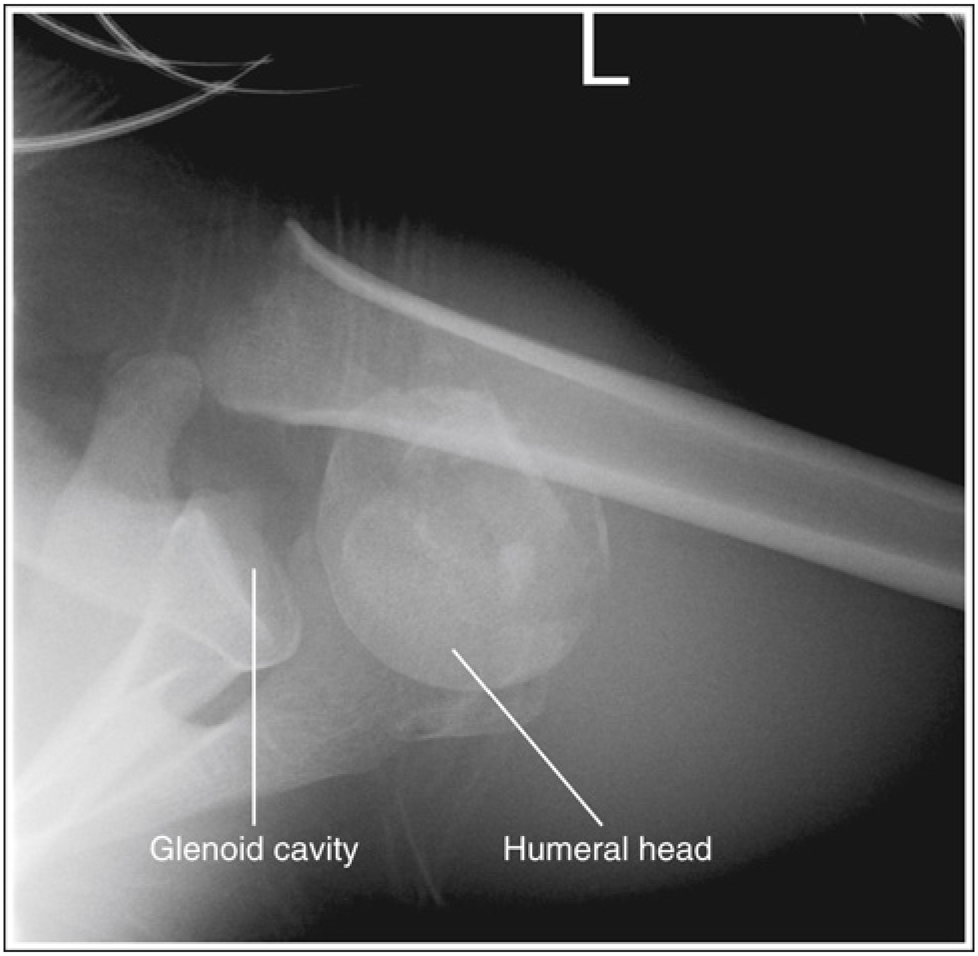


FIGURE 5.26 Inferosuperior axial shoulder projection demonstrating a humeral head fracture.

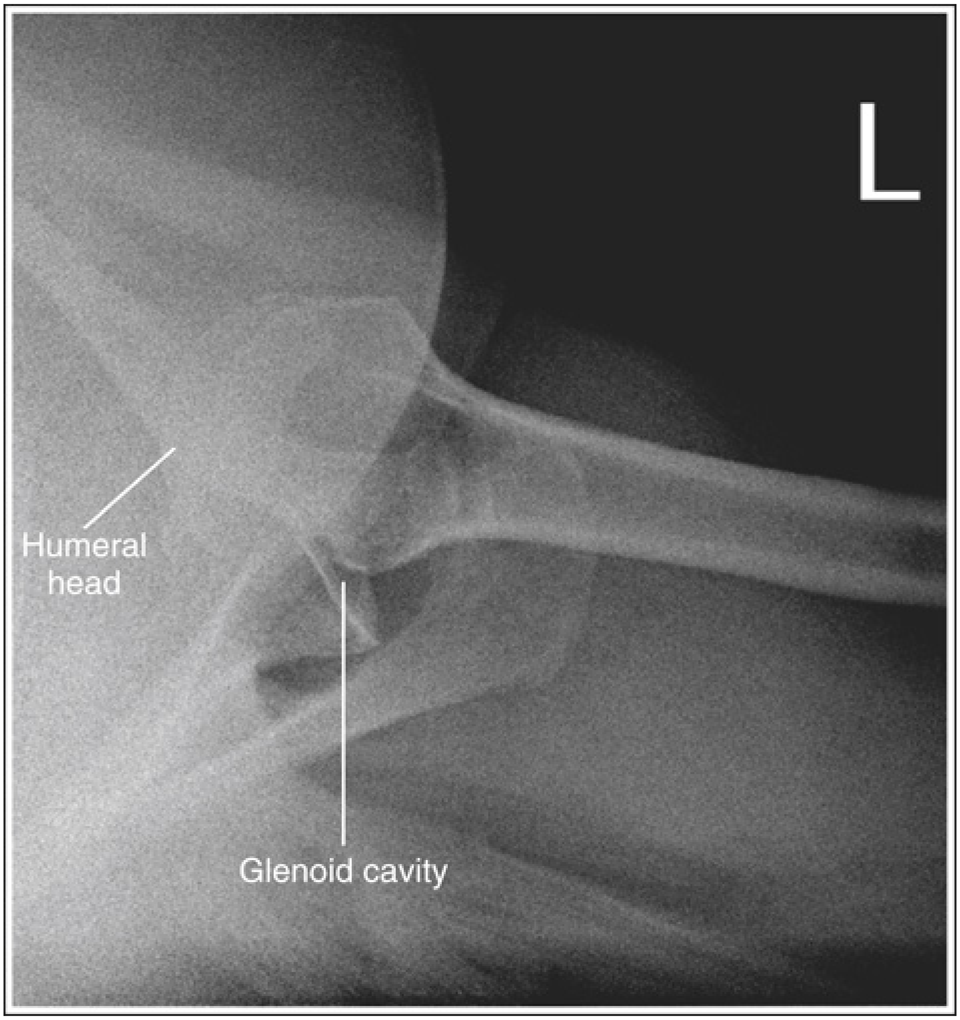


FIGURE 5.27 Inferosuperior axial shoulder projection demonstrating an anterior dislocation and a Hill-Sachs defect.

Humerus Foreshortening

Humeral shaft foreshortening is unavoidable on an inferosuperior axial shoulder projection because the CR cannot be aligned parallel with the glenohumeral joint and perpendicular to the humerus at the same time. As a result, the humeral shaft will always demonstrate some degree of foreshortening, although it can be kept to a minimum as long as the patient is able to abduct the arm to 90 degrees. On the patient who is unable to

abduct the arm to 90 degrees, the humeral shaft demonstrates excessive foreshortening, as identified by the on-end appearance that it will take (**Fig. 5.28**).

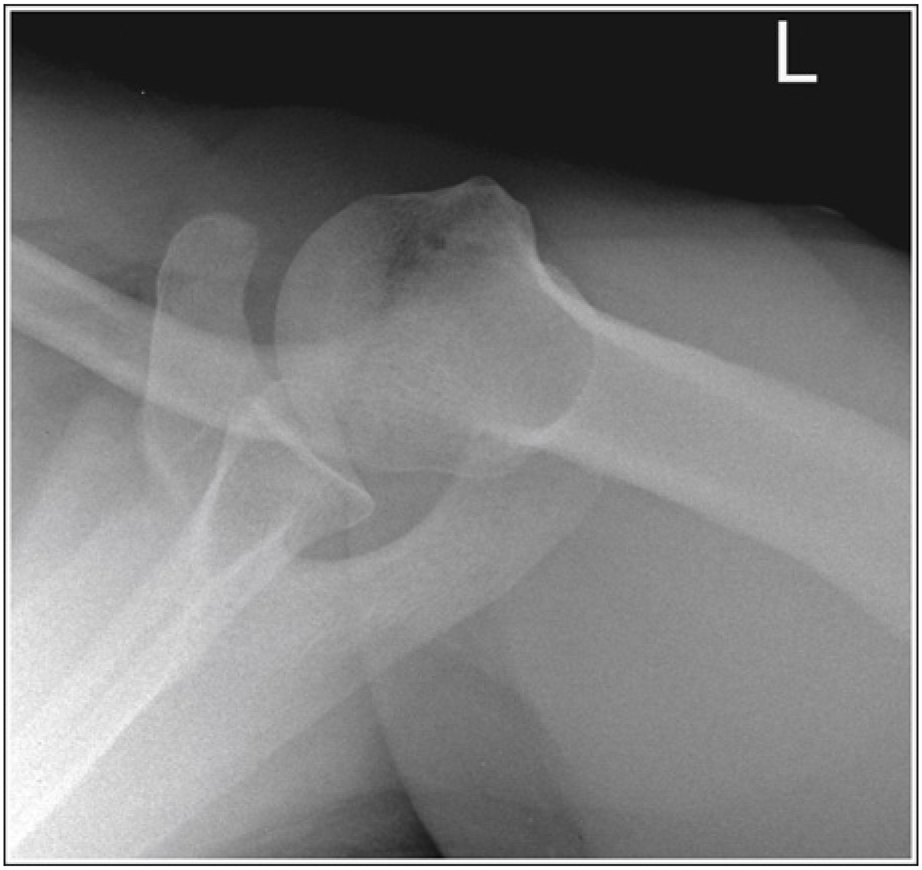


FIGURE 5.28 Inferosuperior axial shoulder projection taken with the arm abducted less than 90 degrees.

Shoulder Retraction

Failure to support the distal humerus so it remains parallel with the floor results in shoulder retraction (**Fig. 5.29**).

FIGURE 5.29 Inferosuperior axial shoulder projection taken with the distal humerus without support to place shoulder in neutral position. Projection demonstrates shoulder retraction.

Humeral Epicondyle Positioning and Humeral Head Visualization

The position of the humeral epicondyles in respect to the floor determines the aspect of the humeral head that will be demonstrated in profile on an inferosuperior axial shoulder. Based on your facilities' expectations for this projection in this regard, use the following to determine how to improve humeral epicondyle positioning to obtain the desired results.

- *If the greater tubercle is seen in partial profile anteriorly*, the humeral epicondyles were in an internally rotated oblique position,

with the medial epicondyle placed closer to the floor than the lateral epicondyle (**Fig. 5.30**).

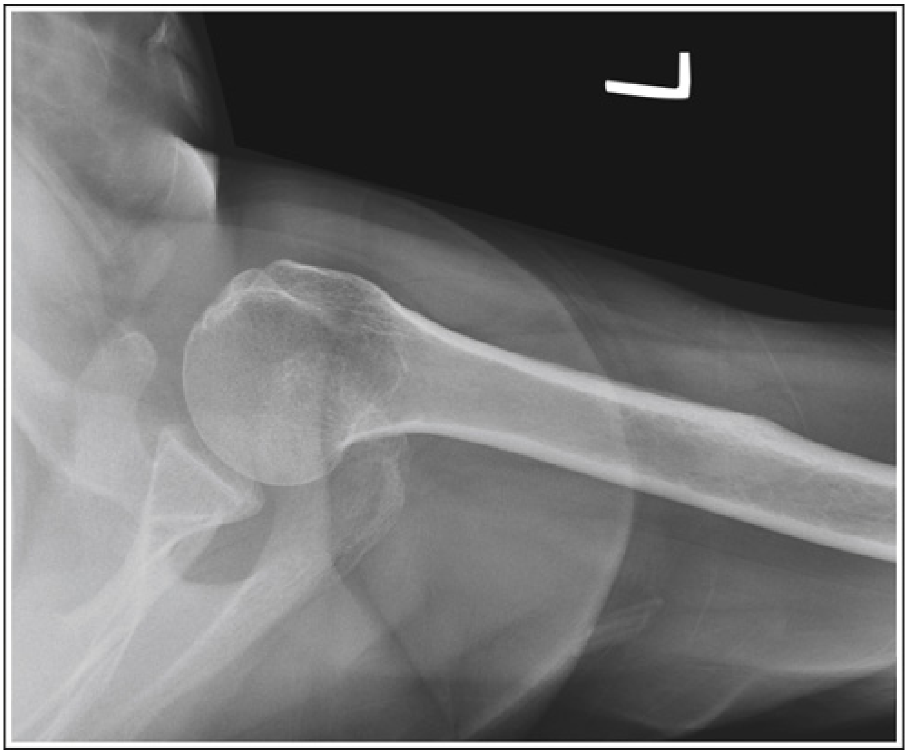


FIGURE 5.30 Inferosuperior axial shoulder projection taken with the humeral epicondyles in an internally rotated oblique position. Greater tubercle is seen in partial profile anteriorly.

- *If the lesser tubercle is seen in profile anteriorly,* the humeral epicondyles were positioned parallel with the floor (see **Figs. 5.18** and **5.23**).
- *If the lesser tubercle is seen in partial profile anteriorly and the posterolateral aspect of the humeral head is seen in profile posteriorly,* the humeral epicondyles were in an externally rotated

45-degree oblique position, with the lateral epicondyle placed closer to the floor (see **Figs. 5.19** and **5.20**).

- *If the greater tubercle is seen in partial profile posteriorly,* the arm was externally rotated until the humeral epicondyles were at a greater than 45-degree angle with the floor (**Fig. 5.31**) and the greater tubercle is seen in full profile posteriorly when the humeral epicondyles are positioned perpendicular to the floor (**Fig. 5.32**). For some patients, this degree of external rotation can only be accomplished by involving the vertebral column as described in the next section.

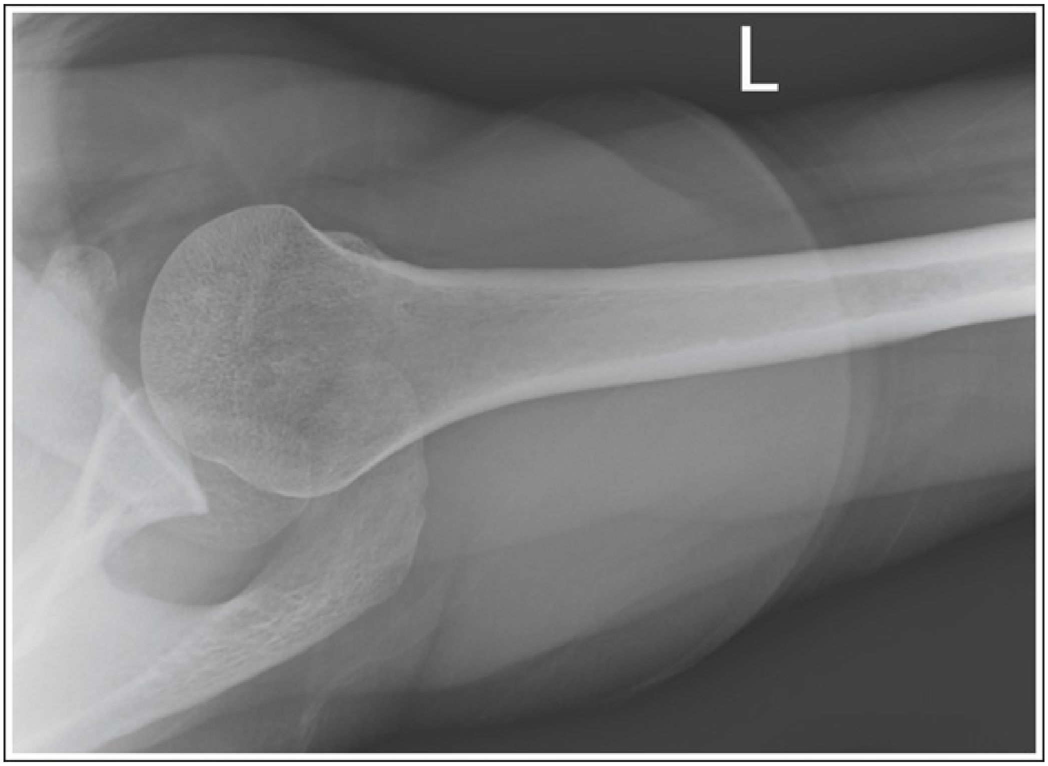


FIGURE 5.31 Inferosuperior axial shoulder projection taken with the arm externally rotated more than 45 degrees with the floor. Greater tubercle is demonstrated in partial profile posteriorly.

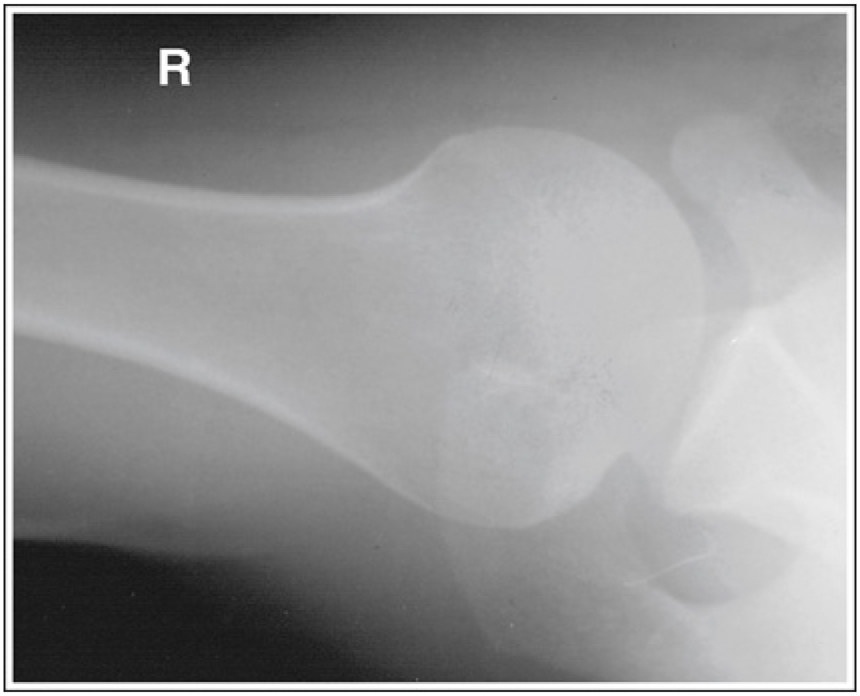


FIGURE 5.32 Inferosuperior axial shoulder projection taken with the arm externally rotated enough to position the humeral epicondyles perpendicular to the floor. Greater tubercle is demonstrated in partial profile posteriorly.

Demonstrating the Hill-Sachs Defect

The Hill-Sachs defect is a notch defect (compression fracture) in the posterolateral aspect of the humeral head created by impingement of the articular surface of the humeral head against the anteroinferior rim of the glenoid cavity that results from anterior shoulder dislocations (see **Fig. 5.27**). This defect is demonstrated on an inferosuperior axial shoulder projection when the humeral epicondyles are placed in the externally rotated 45-degree oblique position.

Coracoid Process and Base

The coracoid process is demonstrated in profile and the coracoid base is seen without scapular neck superimposition when the scapular body remains parallel with the IR. With excessive external arm rotation, the upper thoracic vertebrae arches upward, causing the inferior scapular body to tilt anteriorly, the coracoid to move behind the scapular neck and be less visible, and the space between the scapular neck and acromion to widen (**Fig. 5.33**).

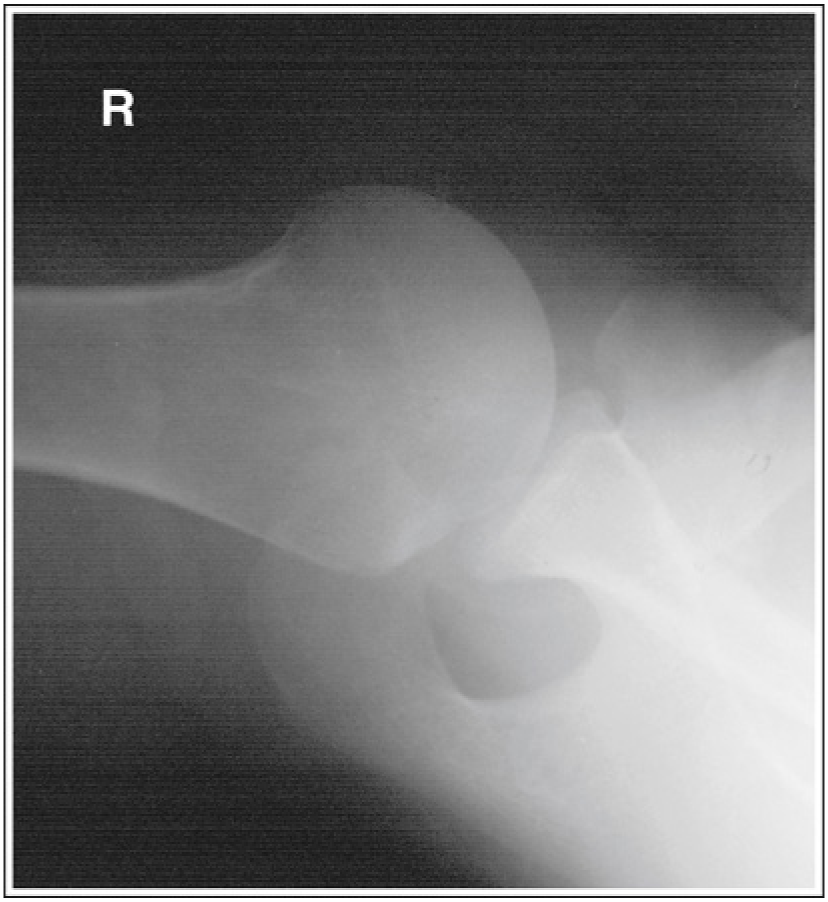


FIGURE 5.33 Inferosuperior axial shoulder projection taken with the humeral epicondyles perpendicular to the floor and the upper thoracic vertebrae arching upwardly.

Including the Posterior Surface

If the shoulder is not elevated the posterior shoulder and humeral structures may not be included on the projection (**Fig. 5.34**).

FIGURE 5.34 Inferosuperior axial shoulder projection taken without the shoulder elevated 2 to 3 inches from the imaging table.

Including the Medial Coracoid

To include the medial coracoid, laterally flex the neck and turn the face away from the affected shoulder. Laterally flexing the neck and turning face allows the IR to be placed more medially in respect to the patient and includes more of the coracoid. If this medial IR placement is not accomplished, the coracoid and other medial structures will not be included (**Fig. 5.35**).

FIGURE 5.35 Inferosuperior axial shoulder projection taken without adequate lateral neck flexion and the IR positioned enough medially.

Pendulous Breast Tissue

On female patients whose breasts move laterally when supine, use the unaffected hand to hold the affected side's breast anteriorly to prevent it from superimposing shoulder anatomy (**Fig. 5.36**). This will also prevent a histogram analysis error due to added anatomy in the value of interest.

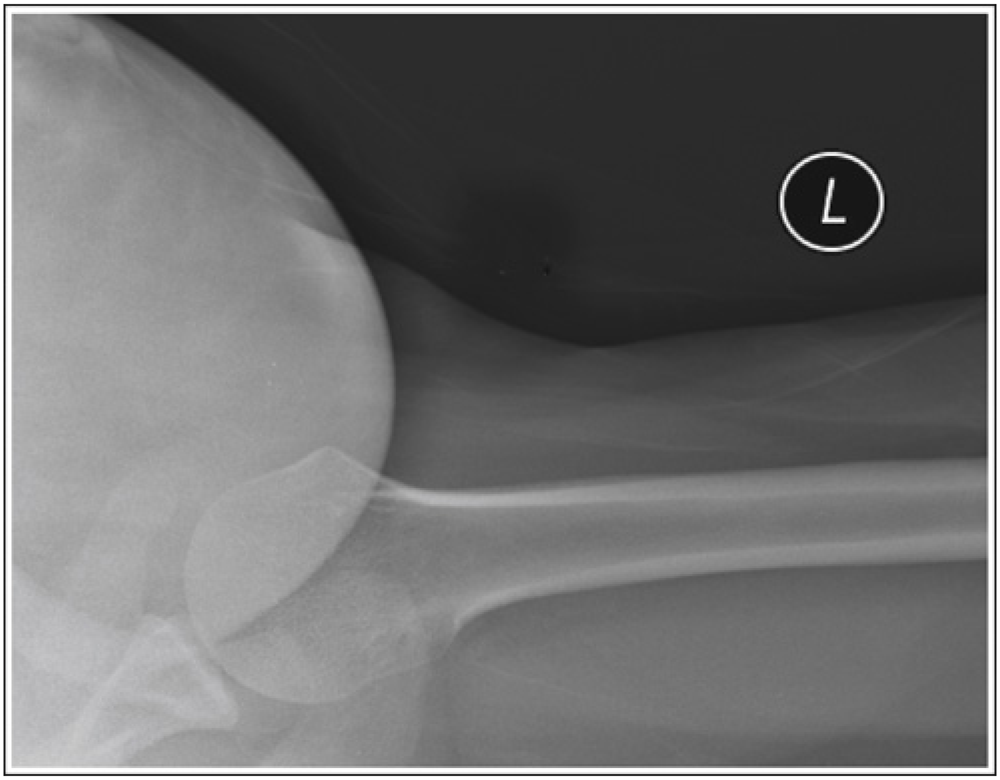


FIGURE 5.36 Inferosuperior axial shoulder projection taken with breast tissue superimposing anatomy of interest.

Inferosuperior Axial Shoulder Analysis Practice

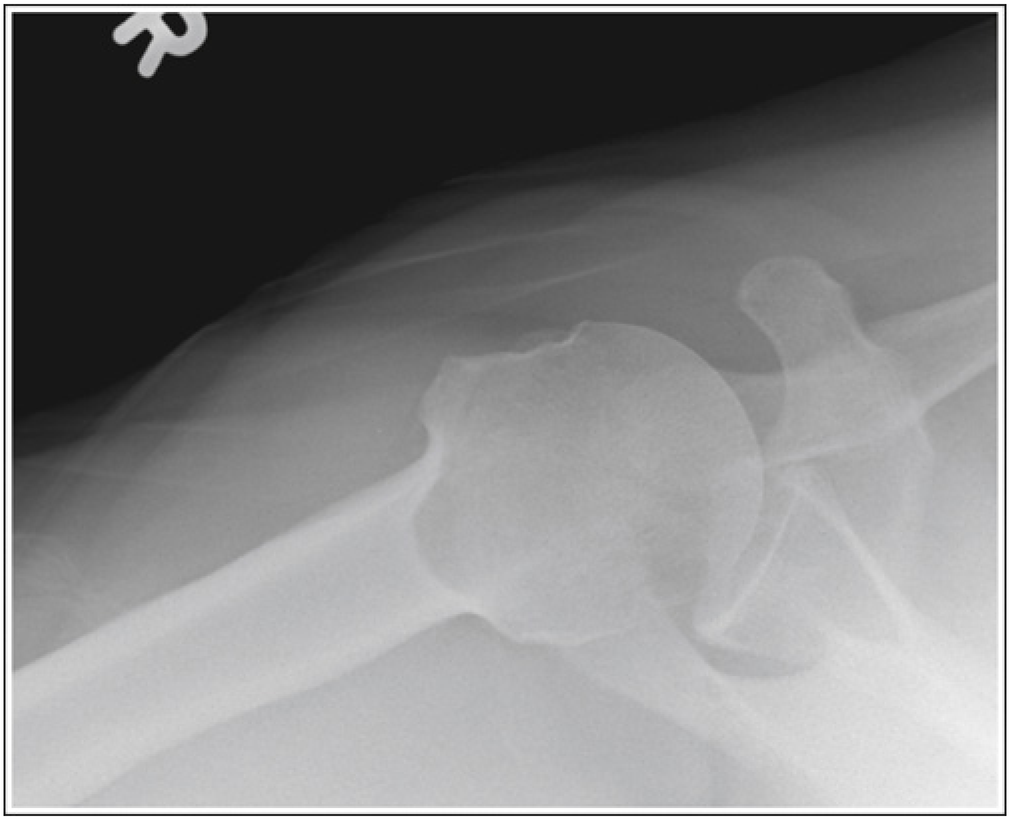


IMAGE 5.4

Analysis

The glenohumeral joint is closed, and the inferior glenoid cavity margin is demonstrated medially to the lateral edge of the coracoid process base and superior glenoid cavity margin, indicating that the angle between the lateral body surface and the CR was too large. The humerus is foreshortened and the humeral head is distorted. The arm was not abducted 90 degrees with the body.

Correction

Decrease the angle between the lateral body surface and CR. If this new CR alignment does not result in the humerus being at a 90-degree angle with

the torso, the humerus should be adjusted to this degree. If the patient cannot abduct the humerus, no humeral corrective movement is necessary.

IMAGE 5.5

Analysis

The glenohumeral joint is closed, and the inferior glenoid cavity margin is demonstrated lateral to the coracoid process base. The angle between the lateral body surface and the CR was less than required to align the CR parallel with the glenohumeral joint.

Correction

Increase the angle between the lateral body surface and the CR to 30 to 35 degrees.

Glenoid Cavity: AP Oblique Projection (Grashey Method)

See **Table 5.4** and **Figs. 5.37**–**5.40**.

TABLE 5.4

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

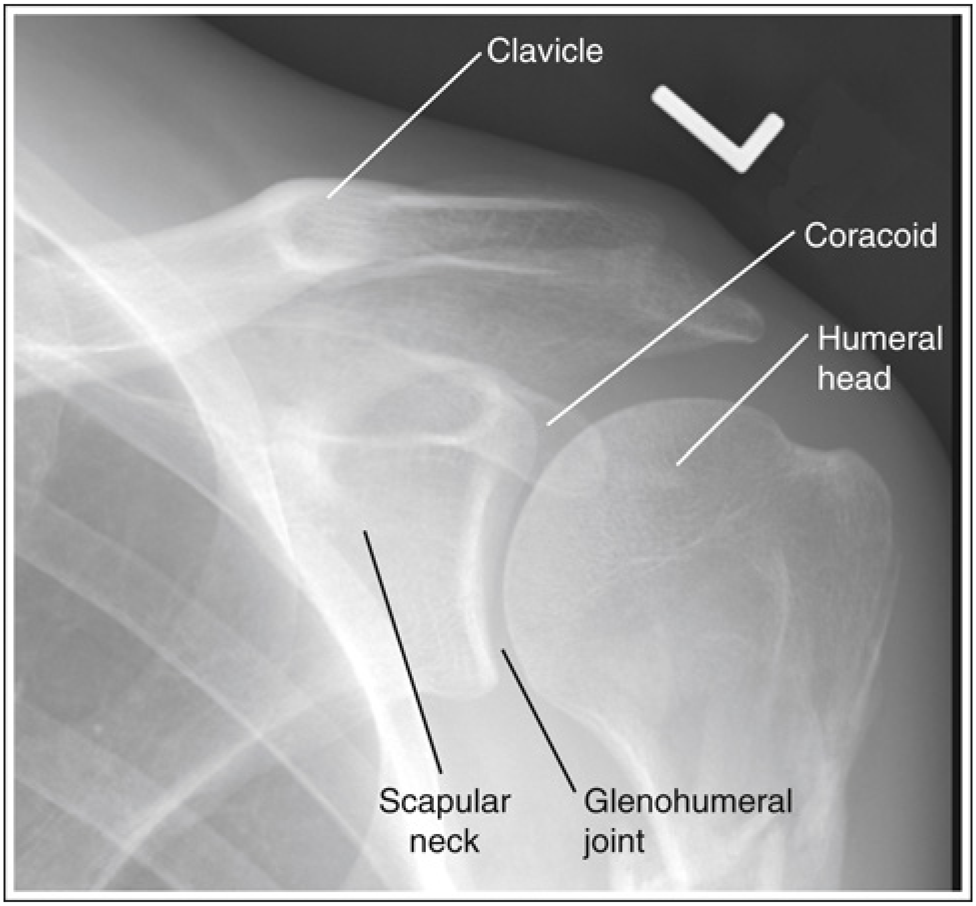


FIGURE 5.37 AP oblique (Grashey) shoulder projection with accurate positioning.

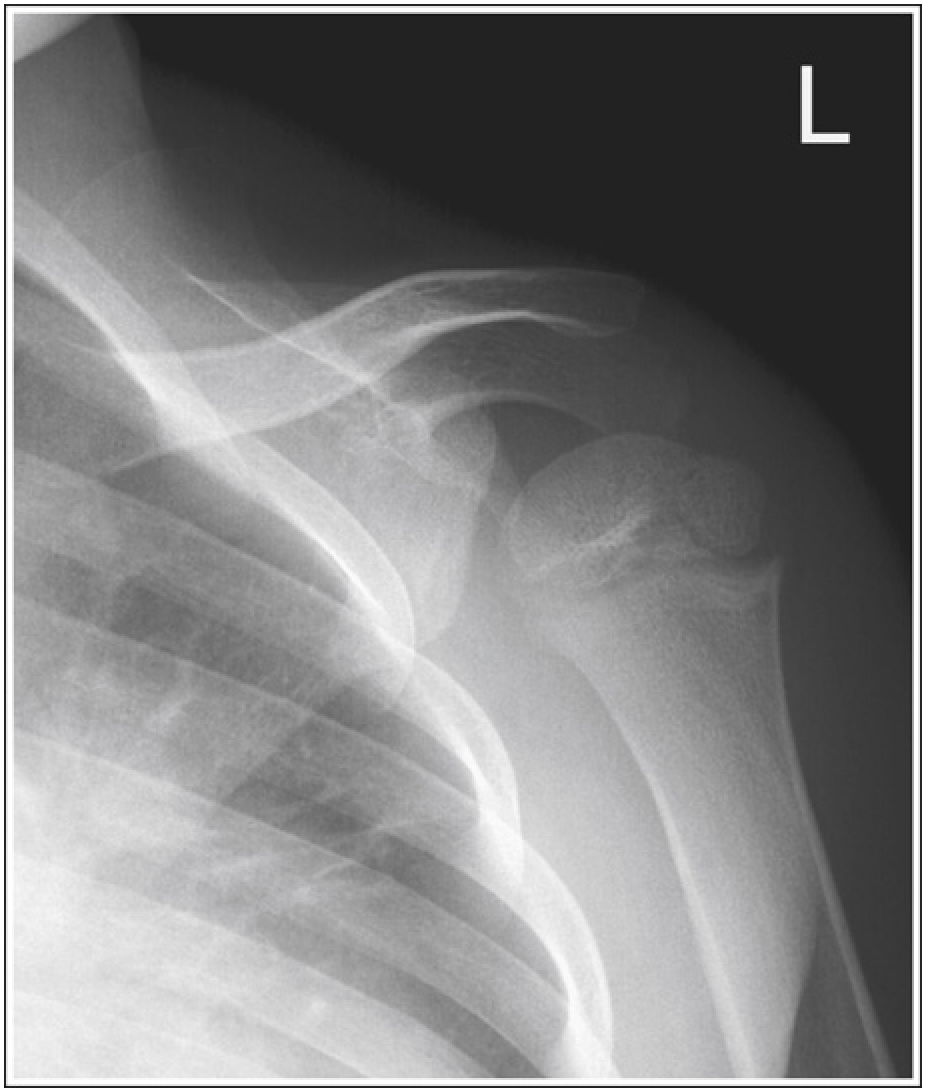


FIGURE 5.38 Pediatric AP oblique (Grashey) shoulder projection with accurate positioning.

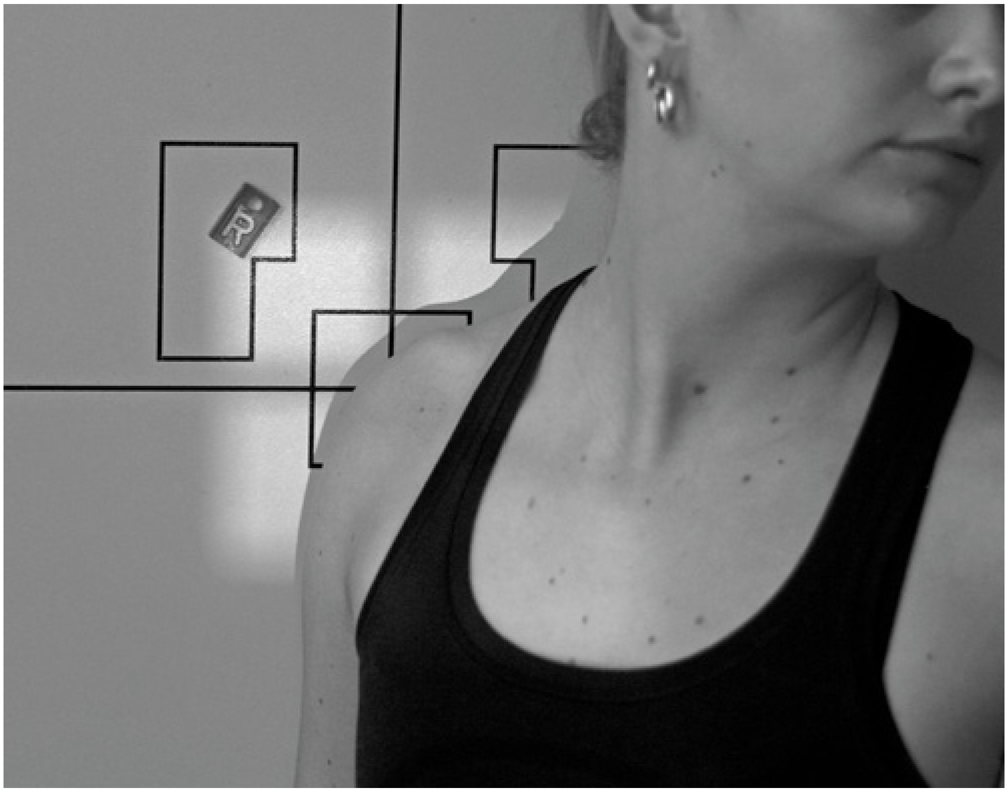


FIGURE 5.39 Proper positioning for AP oblique (Grashey) shoulder projection.

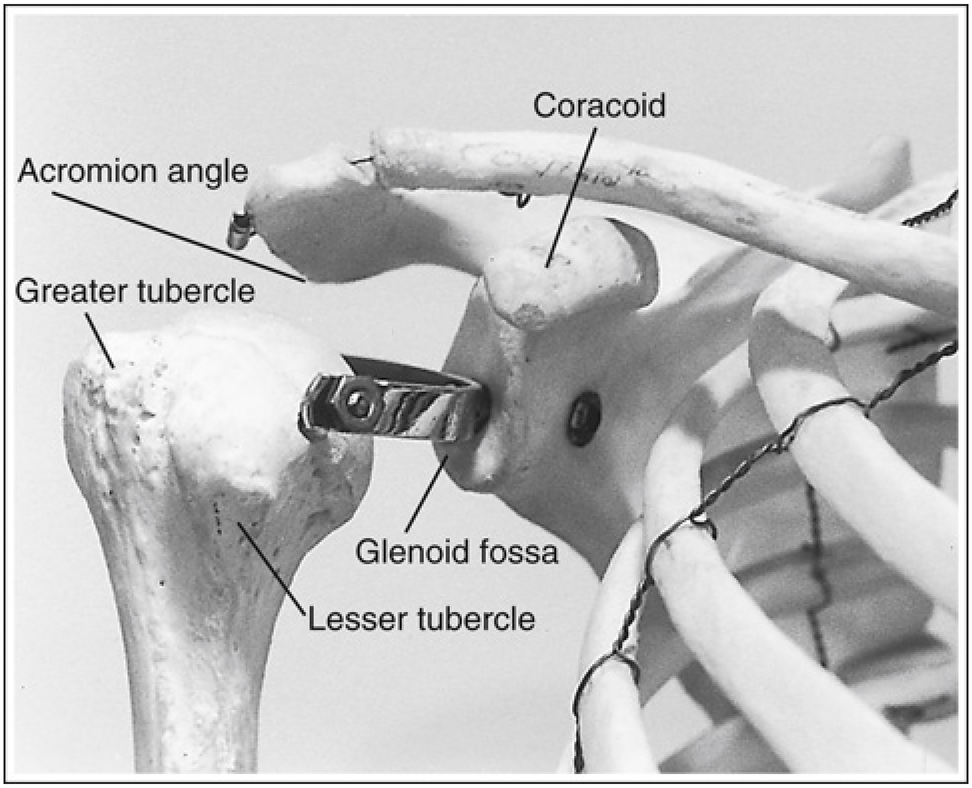


FIGURE 5.40 Shoulder anatomy.

Excessive Torso and Shoulder Rotation

If the torso and shoulder were rotated more than the required amount, the glenohumeral joint space is closed, and more than one-third (0.25 inch [0.6 cm]) of the lateral coracoid process is superimposed over the humeral head (**Fig. 5.41**).

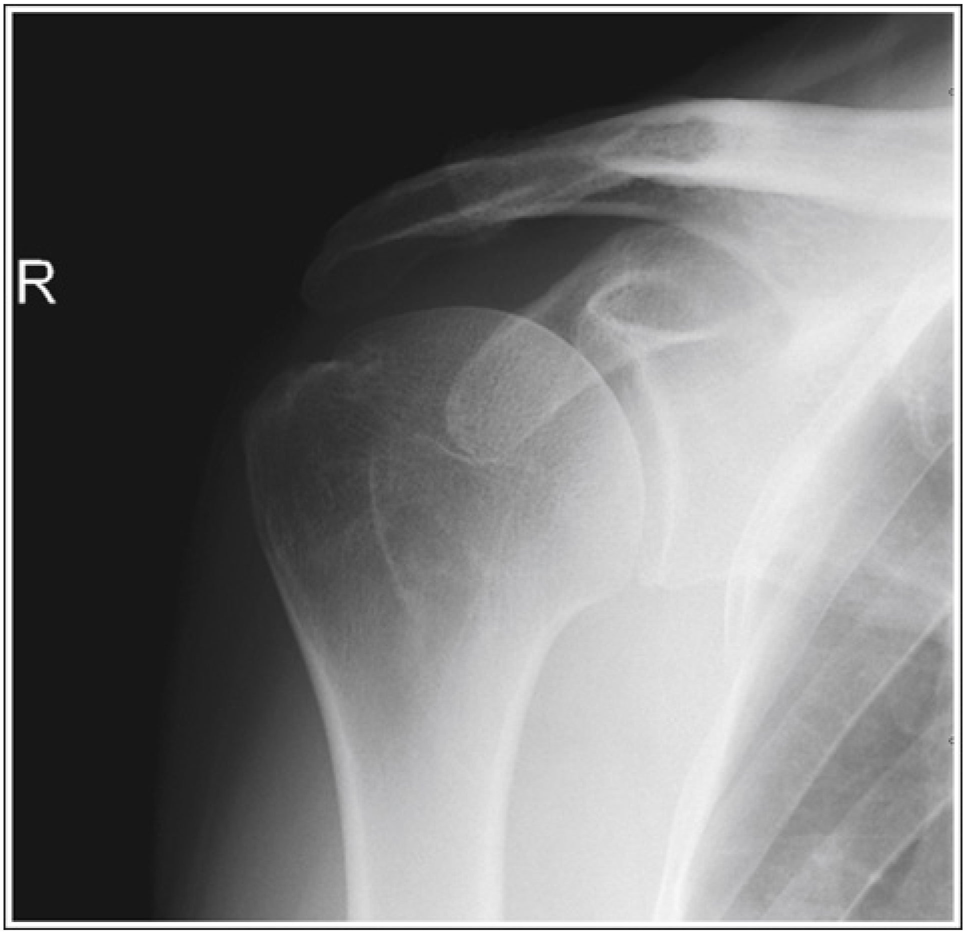


FIGURE 5.41 AP oblique (Grashey) shoulder projection taken with excessive obliquity.

Insufficient Torso and Shoulder Rotation

If the torso and shoulder were rotated less than the required amount, the glenohumeral joint space is closed, and less than one-third (0.25 inch [0.6 cm]) of the coracoid process is superimposing the humeral head (**Fig. 5.42**).

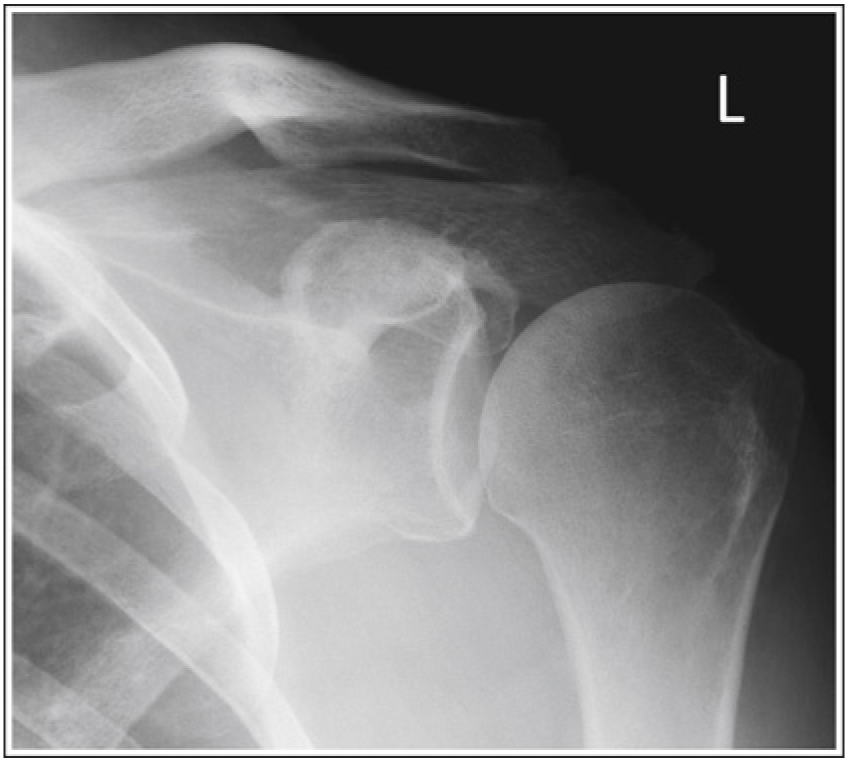


FIGURE 5.42 AP oblique (Grashey) shoulder projection taken with insufficient obliquity.

Patient Differences Requiring a Variation in Torso and Shoulder Obliquity

To place the glenoid cavity in profile and obtain an open glenohumeral joint space, the scapular body is positioned parallel with the IR by rotating the torso 35 to 45 degrees toward the affected shoulder. The amount of torso obliquity that is needed varies between patients because of differences in posture, shoulder roundedness, kyphosis, and degree of shoulder protraction. The more the patient's natural posture moves the scapular anteriorly because of these variations, the more torso obliquity that is needed. One method of determining the amount of patient obliquity necessary for the AP oblique shoulder for all types of variations is to palpate the coracoid process and acromion angle and then rotate the patient

toward the affected shoulder until the coracoid process is superimposed over the acromion angle, aligning an imaginary line connecting them perpendicular to the IR (**Fig. 5.43**).

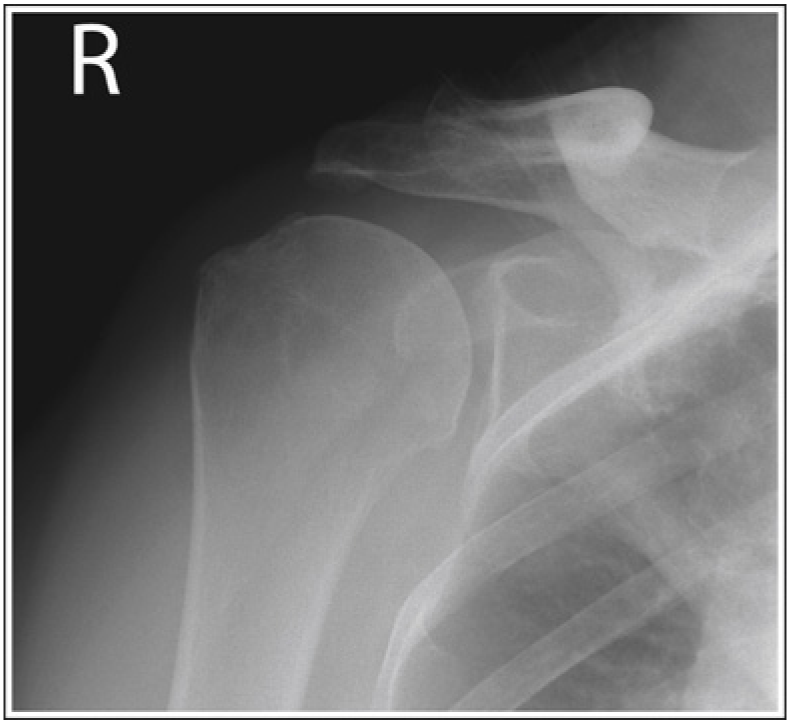


FIGURE 5.43 AP oblique (Grashey) shoulder projection taken with the patient leaning against the IR and shoulder protracted.

Shoulder Protraction

Protraction of the shoulder occurs as a result of pressure that is placed on the affected shoulder when the patient leans against the IR. The sternoclavicular (SC) and acromioclavicular (AC) joints function cooperatively to allow the shoulder to be drawn anteriorly. When the shoulder is protracted, the scapula glides around the thorax, moving it anteriorly. This increase in anterior shoulder positioning places the scapular

body at a larger starting angle with the IR, therefore requiring an increase in torso and shoulder obliquity (up to 60 degrees) to bring the scapular body parallel with the IR for the AP oblique projection.

- *Patient leaning against upright IR.* A projection obtained with the patient leaning against the IR will require increased torso and shoulder obliquity (up to 60 degrees) to open the glenohumeral joint. Because of the increased obliquity, the resulting projection will demonstrate more of the thorax superimposing the glenoid cavity (**Fig. 5.43**).
- *Patient in recumbent position.* Shoulder protraction also occurs and requires an increase in torso and shoulder obliquity when the projection is performed in a recumbent position. In the recumbent position, the pressure of the body on the affected shoulder when the torso is rotated often forces the shoulder to protract and shift superiorly. The protraction requires an increase in torso and shoulder obliquity to open the glenohumeral joint and the superior shifting causes the clavicle to be foreshortened and align more vertically (**Fig. 5.44**).

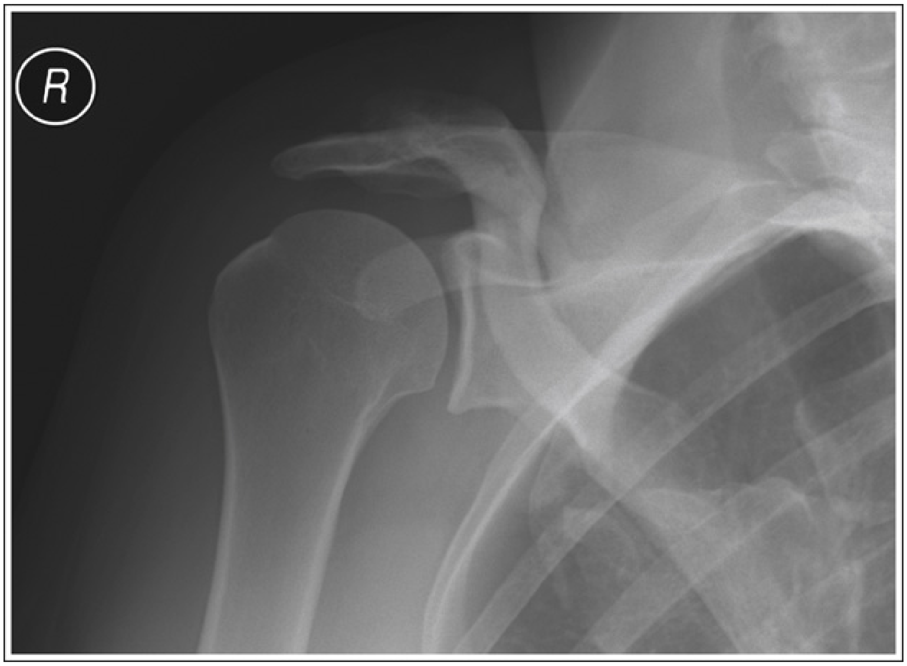


FIGURE 5.44 Accurately positioned recumbent AP oblique (Grashey) shoulder projection demonstrating the clavicle aligned vertically.

- *Kyphotic patient.* The kyphotic patient's increase in spinal convexity prevents the upper midcoronal plane from being straightened and situates the scapula more anteriorly as in maximum shoulder protraction. As a result, AP oblique shoulder projections obtained with the patient positioned as close to the routine for the projection as the patient can accommodate will demonstrate the superior margin of the coracoid demonstrated inferior to the superior margin of the glenoid cavity (**Fig. 5.45**). The alternate positioning methods used in the AP shoulder projection can be used here to offset this appearance. The kyphotic patient will also require increased torso and shoulder obliquity to position the glenoid cavity in profile, and the resulting projection will demonstrate the

thorax closer to or superimposed over the glenohumeral joint space.

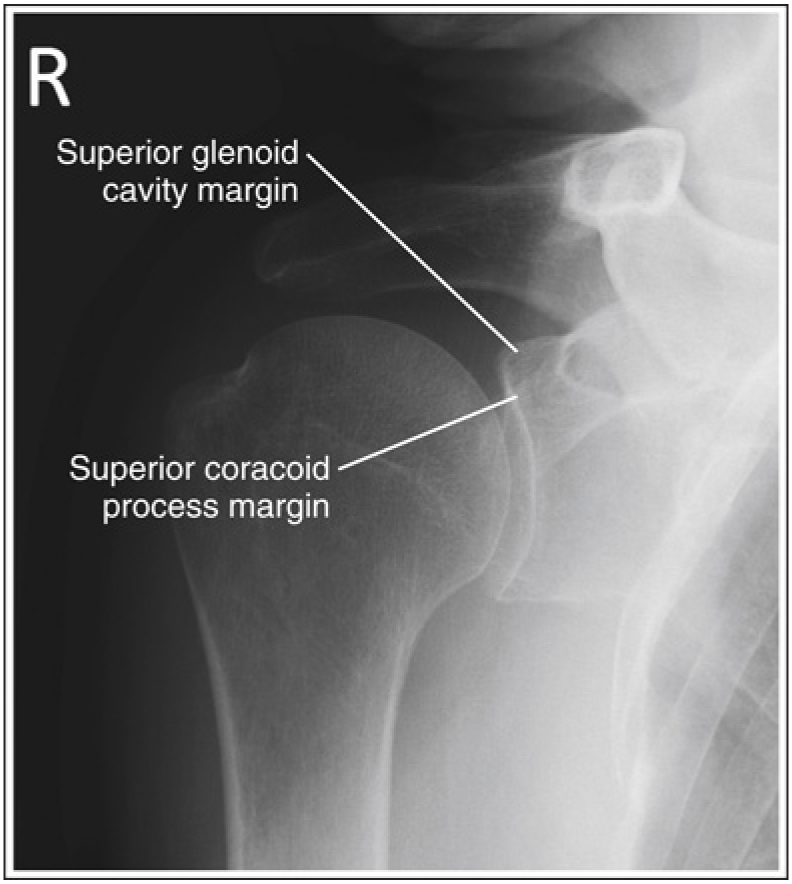


FIGURE 5.45 AP oblique (Grashey) shoulder projection taken on a kyphotic patient or with the upper midcoronal plane tilted anteriorly.

Excessive Torso Obliquity on Recumbent Patient

If torso and shoulder obliquity was excessive for a recumbent AP oblique shoulder, the glenohumeral joint is closed and more than one-third (0.25 inch [0.6 cm]) of the coracoid process superimposes the humeral head on the resulting projection (**Fig. 5.46**).

FIGURE 5.46 Recumbent AP oblique (Grashey) shoulder projection taken with excessive obliquity.

Insufficient Torso Obliquity on Recumbent Patient

If torso and shoulder obliquity were insufficient for a recumbent AP oblique shoulder, the glenohumeral joint is closed and less than one-third (0.25 inch [0.6 cm]) of the coracoid process superimposes the humeral head on the resulting projection (**Fig. 5.47**).

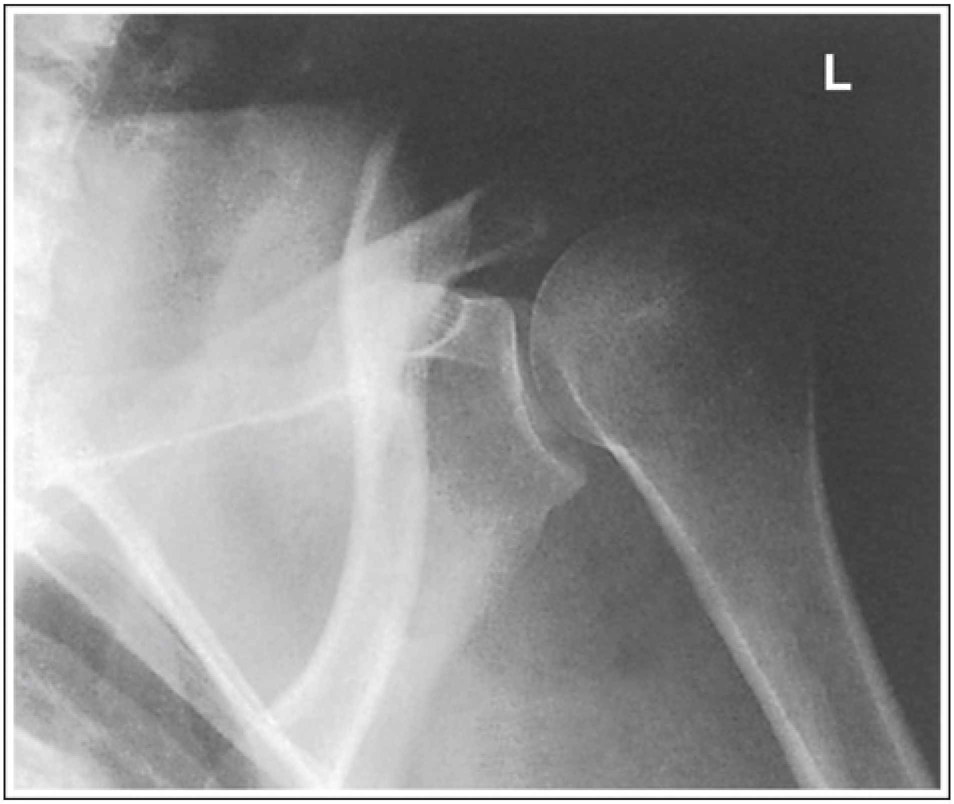


FIGURE 5.47 Recumbent AP oblique (Grashey) shoulder projection taken with insufficient obliquity.

Midcoronal Plane Tilted Anteriorly

If the upper midcoronal plane is tilted anteriorly for an AP oblique shoulder, the superior margin of the coracoid process will be demonstrated inferior to the superior margin of the glenoid cavity in the resulting projection (see **Fig. 5.45**).

Midcoronal Plane Tilted Posteriorly

If the upper midcoronal plane is tilted posteriorly for an AP oblique shoulder, the superior margin of the coracoid process will be demonstrated superior to the superior margin of the glenoid cavity in the resulting projection (**Fig. 5.48**).

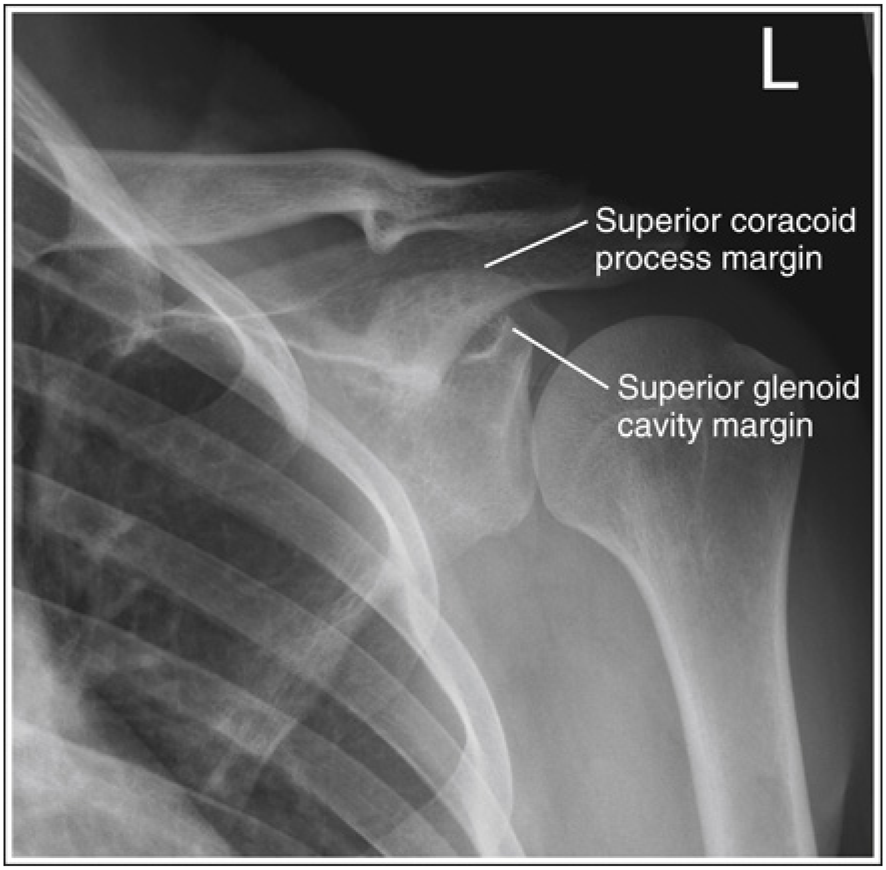


FIGURE 5.48 AP oblique (Grashey) shoulder projection taken with the upper midcoronal plane tilted posteriorly.

AP Oblique Shoulder Analysis Practice

IMAGE 5.6

Analysis

The glenohumeral joint space is closed and less than one-third (0.25 inch [0.6 cm]) of the coracoid process superimposes the humeral head. Torso and shoulder obliquity was insufficient. The superior margin of the coracoid process is superior to the superior margin of the glenoid cavity. The upper midcoronal plane was tilted posteriorly.

Correction

Increase the degree of torso and shoulder obliquity and straighten the midcoronal plane, aligning it parallel with the IR.

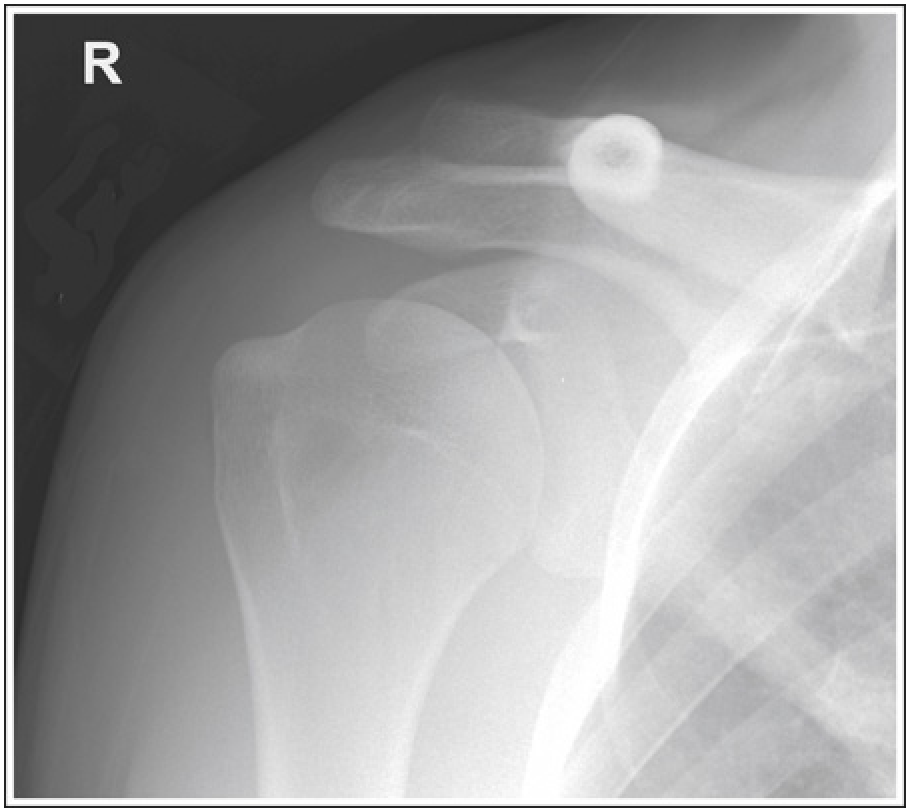


IMAGE 5.7

Analysis

The glenohumeral joint space is closed, more than one-third (0.25 inch [0.6 cm]) of the coracoid process superimposes the humeral head. Torso and shoulder obliquity was excessive.

Correction

Decrease the degree of torso and shoulder obliquity.

Scapular Y: PA Oblique Projection

See **Table 5.5** and **Figs. 5.49** and **5.50**.

TABLE 5.5

CR, Central ray; *IR*, image receptor; *PA*, posteroanterior.

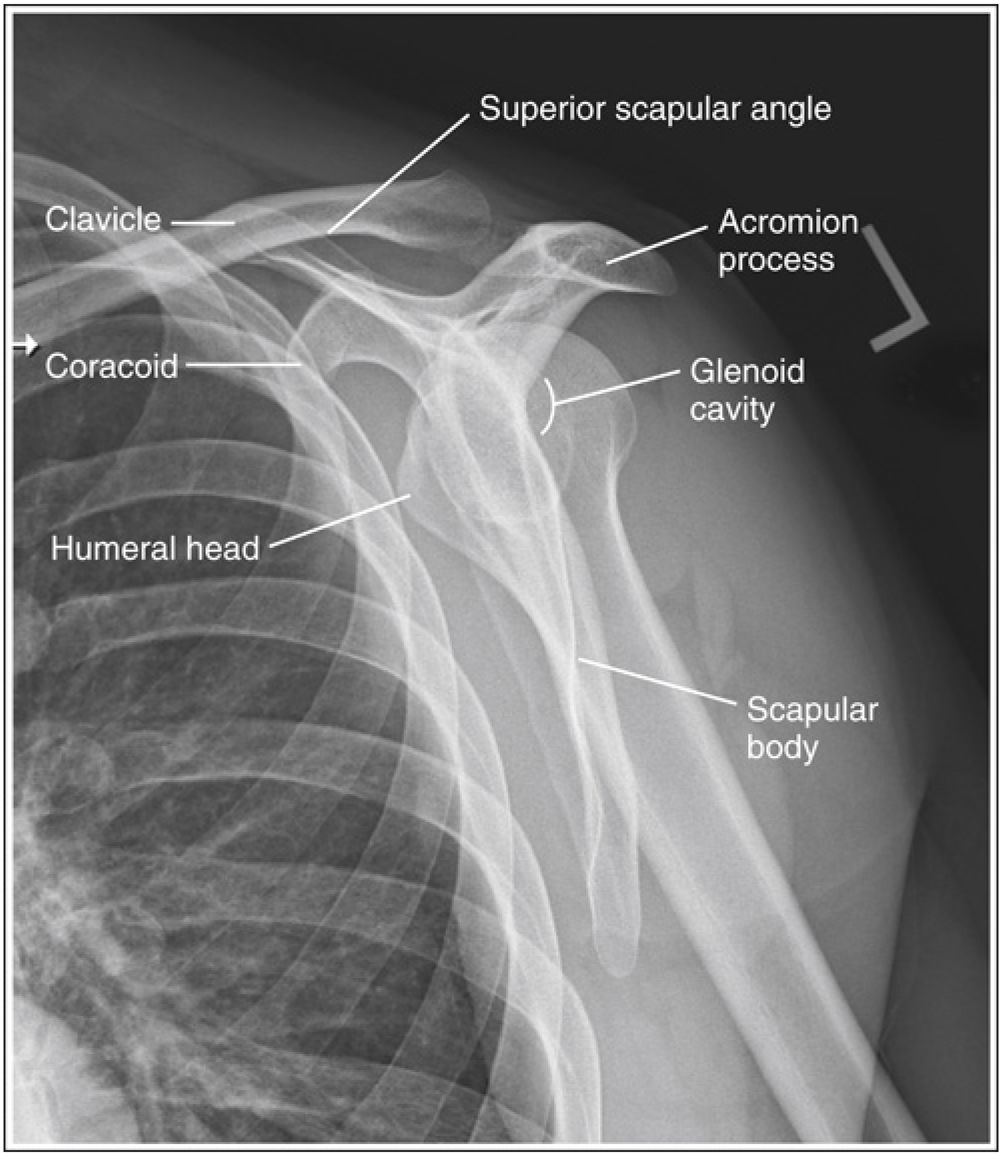


FIGURE 5.49 PA oblique (scapular Y) shoulder projection with accurate positioning.

FIGURE 5.50 Proper PA oblique (scapular Y) positioning.

Excessive Torso and Shoulder Obliquity

If the lateral border is superimposed by the thorax or is positioned closer to the thorax than the vertebral border, the obliquity was excessive (**Fig. 5.51**). The glenoid cavity will rotate in the same direction as the lateral border.

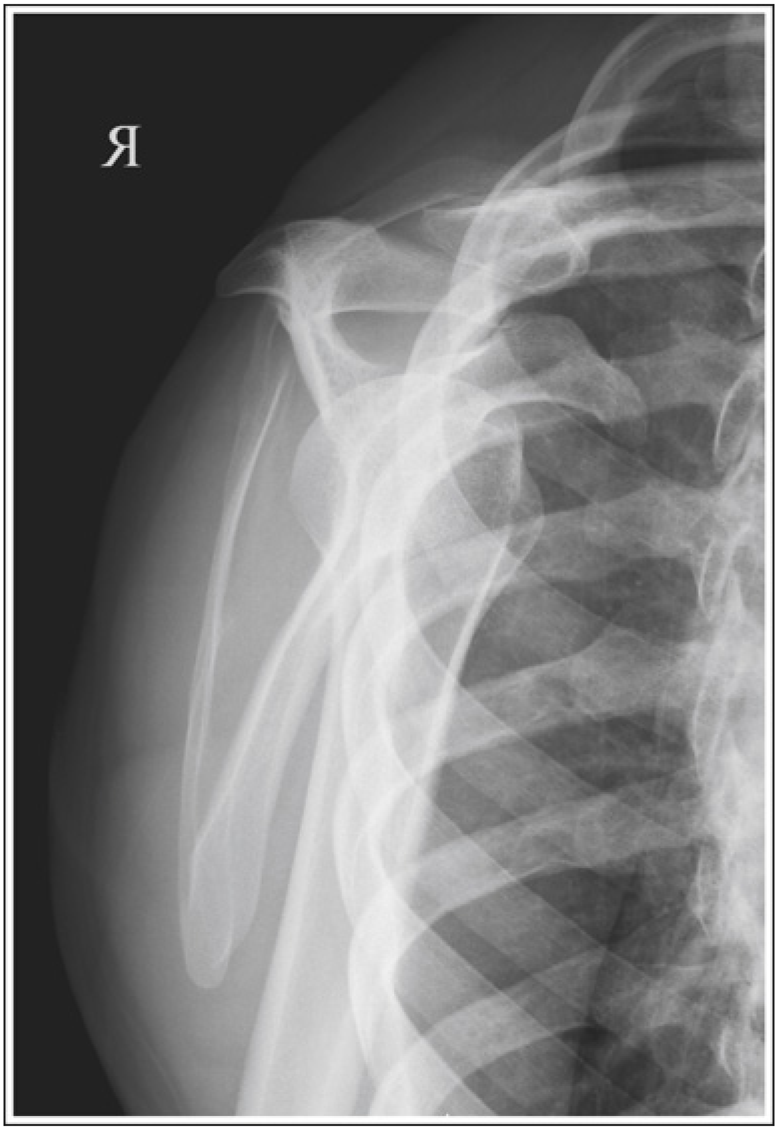


FIGURE 5.51 PA oblique (scapular Y) shoulder projection taken with excessive scapular obliquity.

Identifying the Scapular Borders When a Lateral Is Not Obtained

The lateral border is thick, with two cortical outlines that are separated by approximately 0.25 inch (0.6 cm), whereas the cortical outline of the vertebral border demonstrates a single thin line (**Fig. 5.52**).

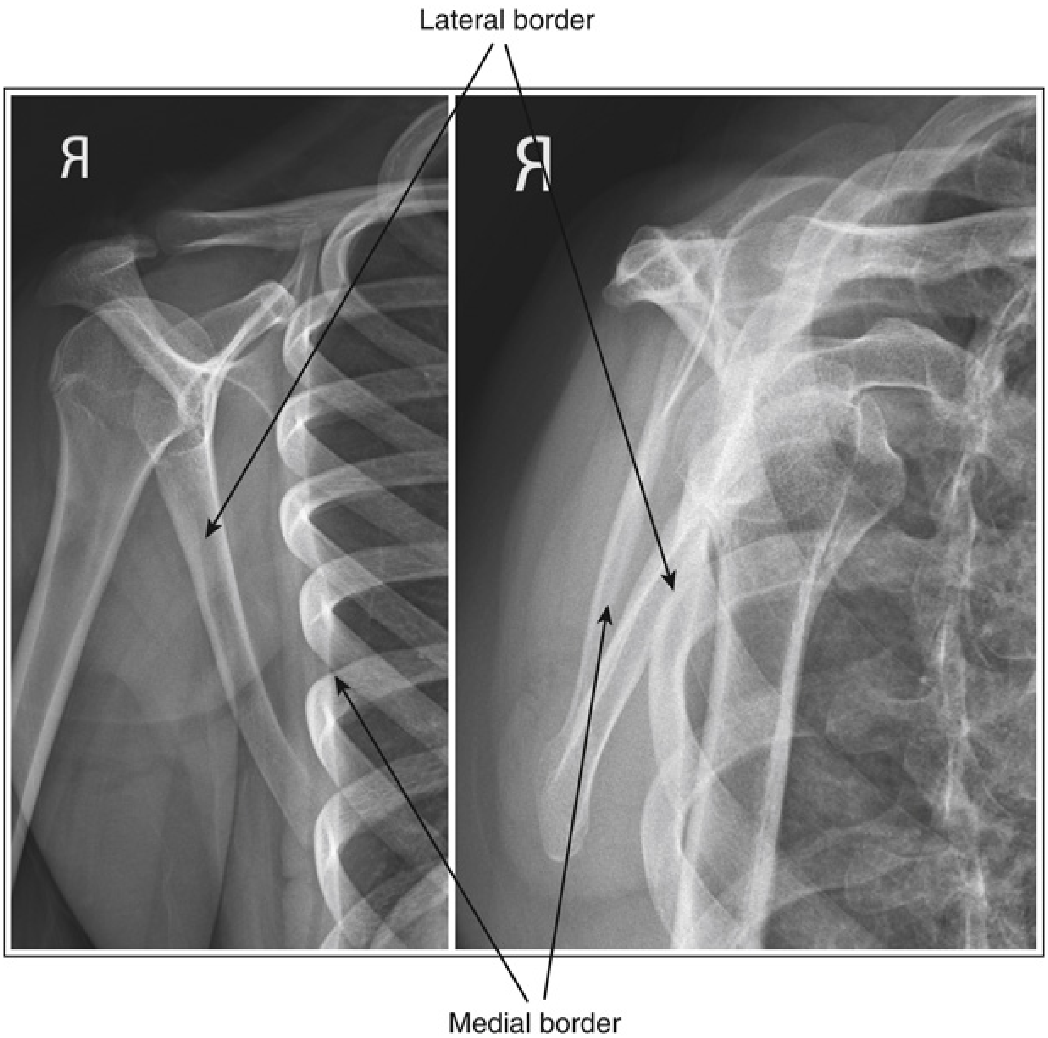


FIGURE 5.52 Identifying the scapular borders.

Insufficient Torso and Shoulder Obliquity

If the vertebral border superimposes the thorax or is demonstrated closer to the thorax than the lateral border on a PA oblique shoulder projection, the obliquity was insufficient (**Fig. 5.53**). The glenoid cavity will rotate in the same direction as the lateral border.

FIGURE 5.53 PA oblique (scapular Y) shoulder projection taken with insufficient scapular obliquity.

Shoulder Dislocation

The cortical outline of the glenoid cavity is visible as a circular density at the junction of the coracoid and acromion processes and the scapular body. Normally the humeral head is superimposed over this junction. When the humeral head is not positioned over the glenoid cavity, a shoulder

dislocation exists and will result in positioning of the humeral head anterior or posterior and inferior to the glenoid cavity. An anterior dislocation results in the humeral head being demonstrated anteriorly, beneath the coracoid process (**Fig. 5.54**). A posterior dislocation results in the humeral head being demonstrated posteriorly, beneath the acromion process (**Fig. 5.55**).

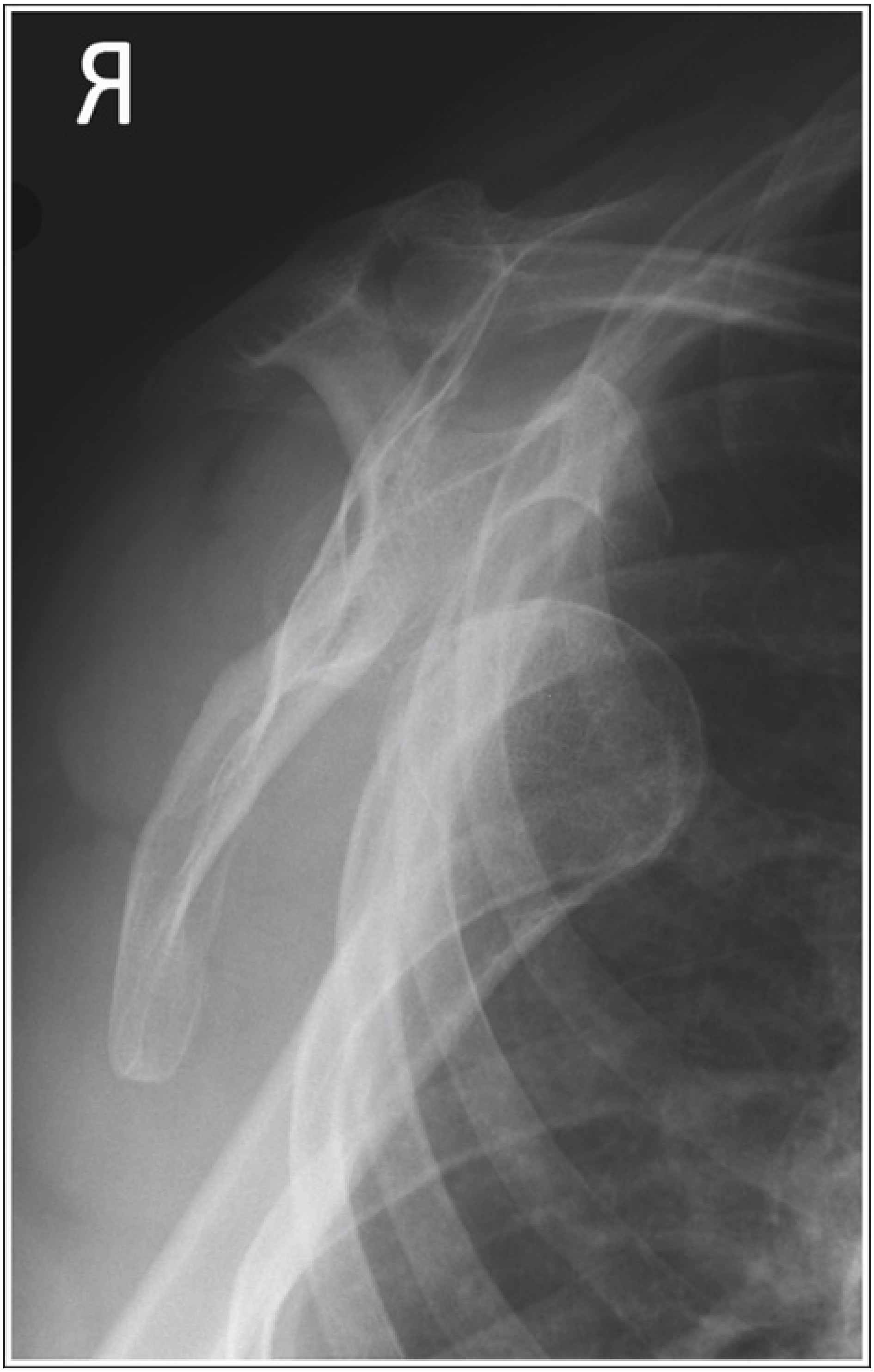


FIGURE 5.54 PA oblique (scapular Y) shoulder projection demonstrating an anterior dislocation.

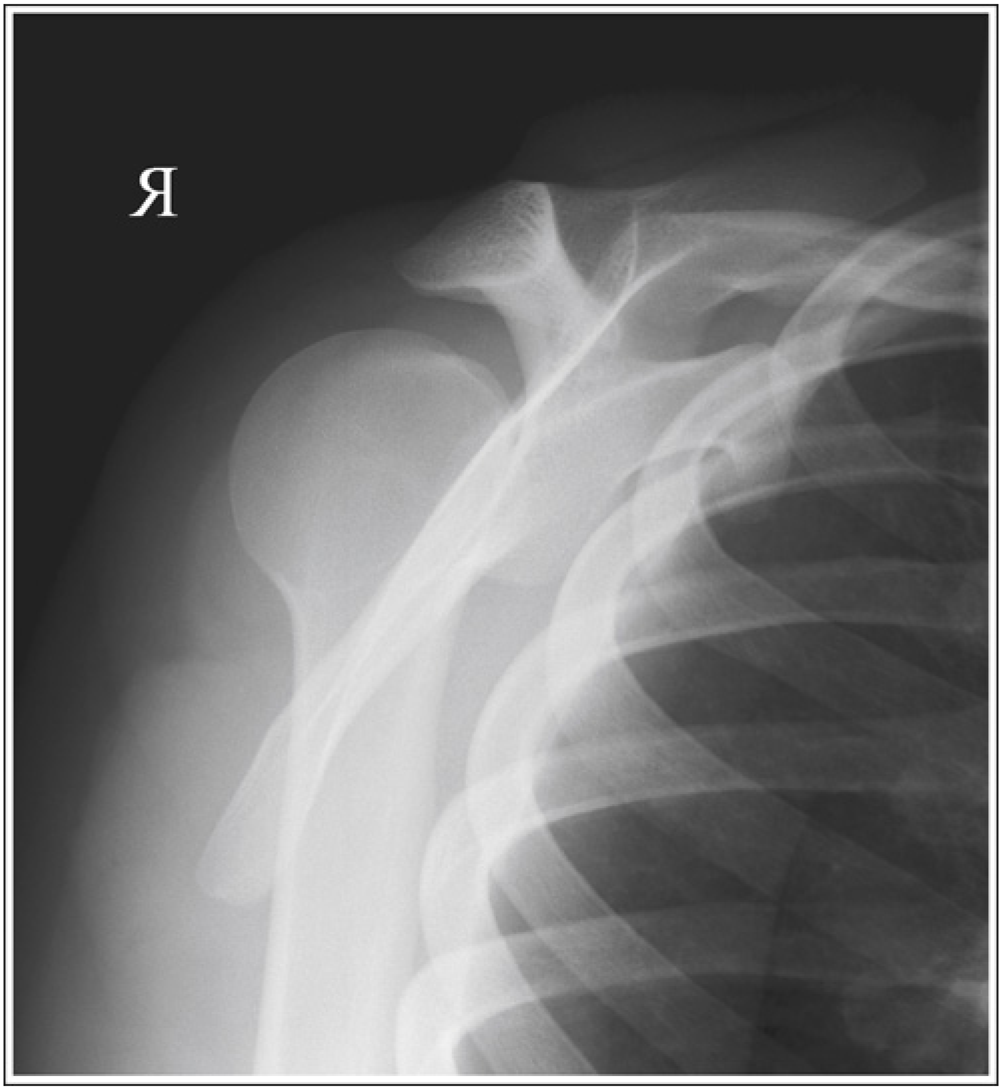


FIGURE 5.55 PA oblique (scapular Y) shoulder projection demonstrating a posterior dislocation.

Proximal Humeral Fracture

PA oblique projection taken of a patient with a proximal humeral fracture will typically demonstrate superimposition of the humeral head and glenoid cavity, but the humeral shaft will be positioned anteriorly or posteriorly to the scapular body (**Fig. 5.56**). It is important that a correct Y formation of the scapula be accomplished when a fracture is suspected to identify its true

relationship to the humeral shaft. **Fig. 5.57** demonstrates projections obtained on the same patient. Compare the accuracy of the scapular Y formation and the alignment of the humeral head and shaft on these projections.

FIGURE 5.56 PA oblique (scapular Y) shoulder projection demonstrating a humeral head and neck fracture.

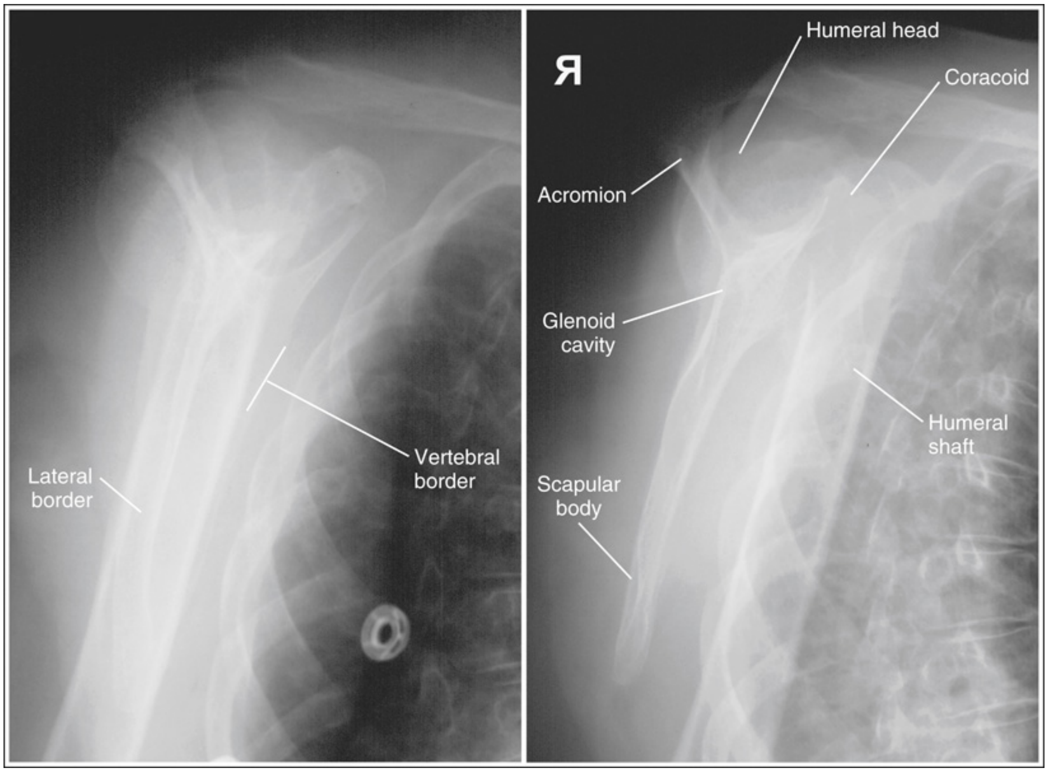


FIGURE 5.57 PA oblique (scapular Y) shoulder projections demonstrating a proximal humeral fracture, with insufficient obliquity and accurate positioning.

Upper Midcoronal Plane Tilted Anteriorly

Longitudinal scapular foreshortening on a PA oblique projection is a result of leaning the upper midcoronal plane and shoulder toward or away from the IR. When the patient is leaning toward the IR, the superior scapular angle is demonstrated superior to the clavicle (**Fig. 5.58**).

FIGURE 5.58 PA oblique (scapular Y) shoulder projection taken with the upper midcoronal plane tilted anteriorly.

Upper Midcoronal Plane Tilted Posteriorly

When the patient is leaning away from the IR for a PA oblique shoulder, the resulting projection demonstrates the superior scapular angle inferior to the clavicle (**Fig. 5.59**).

FIGURE 5.59 PA oblique (scapular Y) shoulder projection taken with the upper midcoronal plane tilted posteriorly.

Kyphotic Patient

On patients with spinal kyphosis or who have shoulders that are rounded anteriorly, the scapula is situated such that longitudinal foreshortening of the body will occur even when positioned as indicated in **Table 5.4**. To offset this curvature and obtain a scapula with reduced foreshortening, the CR may be angled until it is aligned perpendicular to the vertebral border of

the scapula. These conditions will also require less torso and scapular obliquity to superimpose the medial and lateral scapular borders. For the PA oblique projection, the angulation would be caudal, and for AP oblique projection, the angulation would be cephalad.

Recumbent Patient: AP Oblique Projection

For a patient who is recumbent and unable to stand, the scapular Y formation can be obtained by means of an AP oblique projection. To position the patient, palpate the acromion and coracoid processes and vertebral scapular borders in the same way as described for the standing PA oblique projection, except rotate the torso toward the unaffected shoulder. The anatomic relationship of the bony structures of the scapula and clavicle should be aligned identically on PA and AP oblique projections. The AP oblique projection, however, demonstrates increased magnification of the scapula and humerus (**Fig. 5.60**).

FIGURE 5.60 Properly positioned AP oblique (scapular Y) shoulder projection.

PA Oblique (Scapular Y) Shoulder Analysis Practice

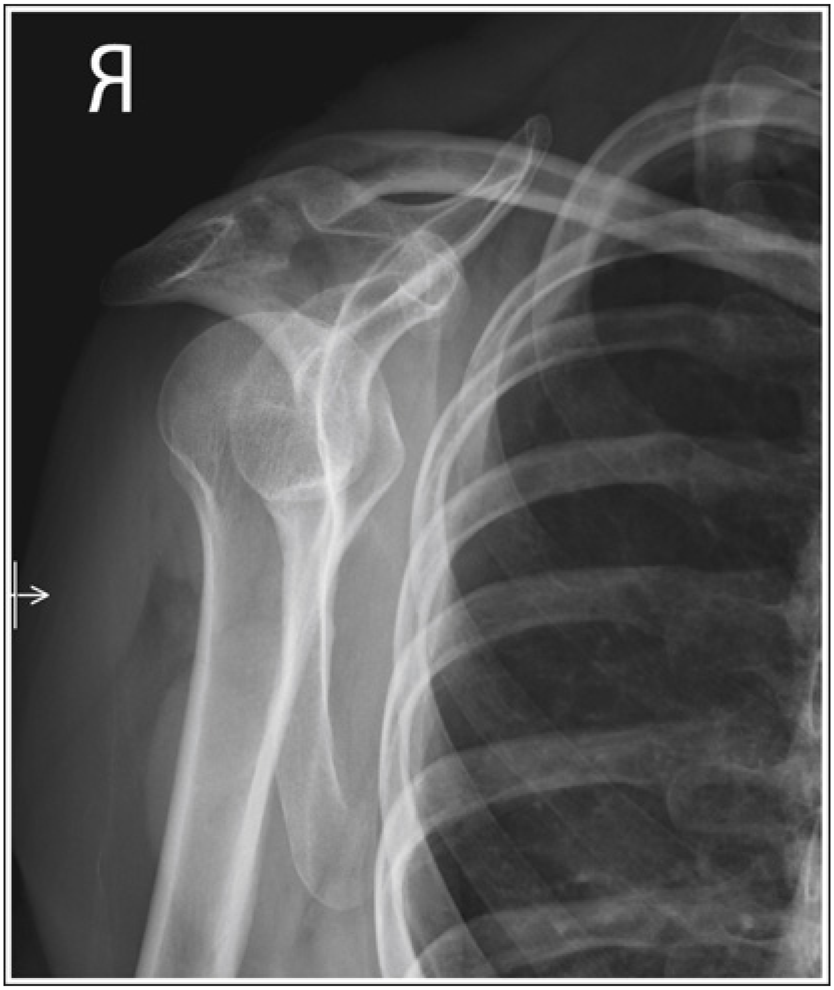


IMAGE 5.8

Analysis

The lateral and vertebral borders of the scapula are demonstrated without superimposition, and the glenoid cavity is not demonstrated on end but is seen laterally. The vertebral scapular borders are demonstrated next to the ribs. The torso and shoulder were insufficiently rotated.

Correction

Increase the torso obliquity.

IMAGE 5.9

Analysis

The scapular body, acromion, and coracoid processes are accurately aligned, but the superior scapular angle is demonstrated superior to the clavicle. The scapula is foreshortened. The upper midcoronal plane was leaning toward the IR.

Correction

Straighten the upper midcoronal plane, aligning it parallel with the IR.

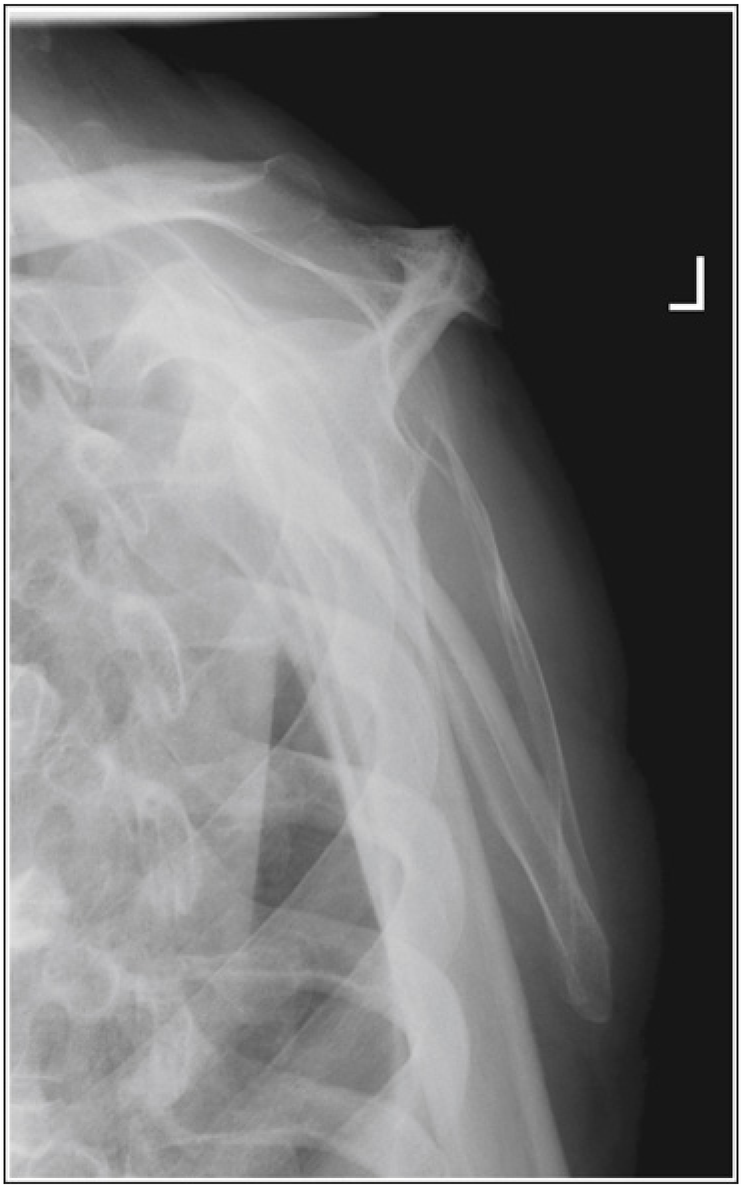


IMAGE 5.10

Analysis

The lateral and vertebral borders of the scapula are demonstrated without superimposition, and the glenoid cavity is not demonstrated on end but is shown medially. The lateral scapular borders are demonstrated next to the ribs. The torso was rotated more than needed to superimpose the borders of the scapular body.

Correction

Decrease the degree of torso obliquity.

Proximal Humerus: AP Axial Projection (Stryker Notch Method)

See **Table 5.6** and **Figs. 5.61** and **5.62**.

TABLE 5.6

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

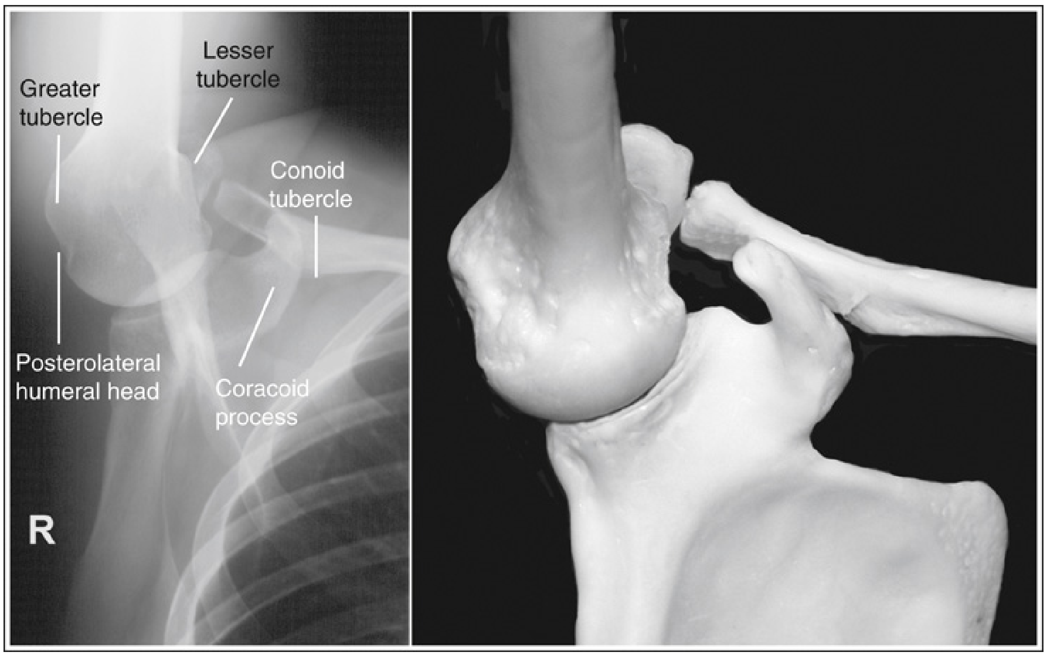


FIGURE 5.61 AP axial (Stryker) shoulder projection with accurate positioning.

FIGURE 5.62 Proper AP axial (Stryker) shoulder projection positioning.

Torso Rotated Away From Affected Shoulder

If the torso is rotated away from the affected shoulder for an AP axial shoulder, the coracoid process superimposes the conoid tubercle and more of the glenoid cavity will be demonstrated on the resulting projection.

Torso Rotated Toward Affected Shoulder

If the torso is rotated toward the affected shoulder for an AP axial shoulder, the coracoid process moves away from the conoid tubercle and less of the glenoid cavity will be demonstrated on the resulting projection.

Upper Midcoronal Plane Tilted Anteriorly or CR Angle Too Caudally

If the upper midcoronal plane is tilted anteriorly, or if less than a 10-degree cephalad CR angle is used for an AP axial shoulder, the coracoid process is demonstrated inferior to the clavicle and the CR will not be properly aligned with the humeral head, causing the posterolateral aspect of the humeral head to be obscured on the resulting projection. The humeral shaft will also demonstrate increased foreshortening (**Fig. 5.63**).

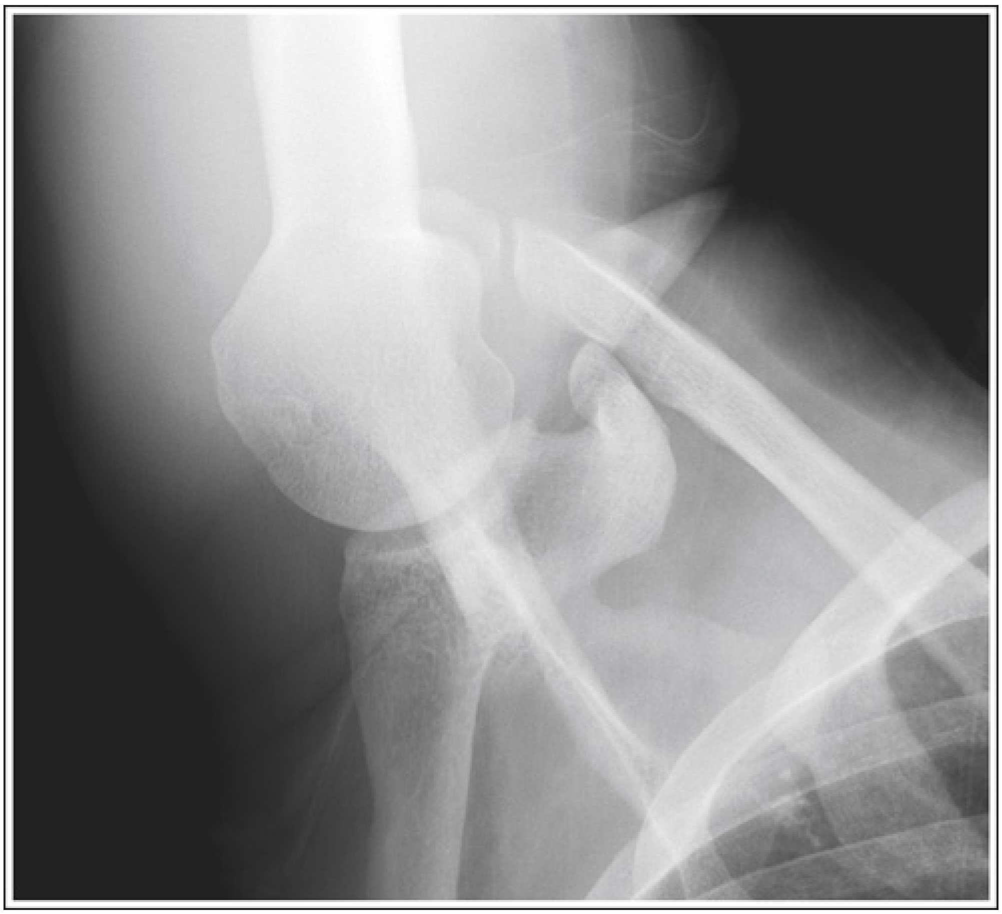


FIGURE 5.63 AP axial (Stryker) shoulder projection taken with upper midcoronal plane tilted anteriorly or with less than a 10-degree cephalad CR angulation.

Humeral Abduction Beyond Vertical

The posterolateral aspect of the humeral head is obscured on an AP axial shoulder projection when the CR is accurately angled, but the humerus is poorly abducted. If the humerus is abducted beyond vertical, the humeral head obscures the posterolateral humeral head and is identified by the decrease in humeral shaft foreshortening and the lateral clavicle elevated (**Fig. 5.64**).

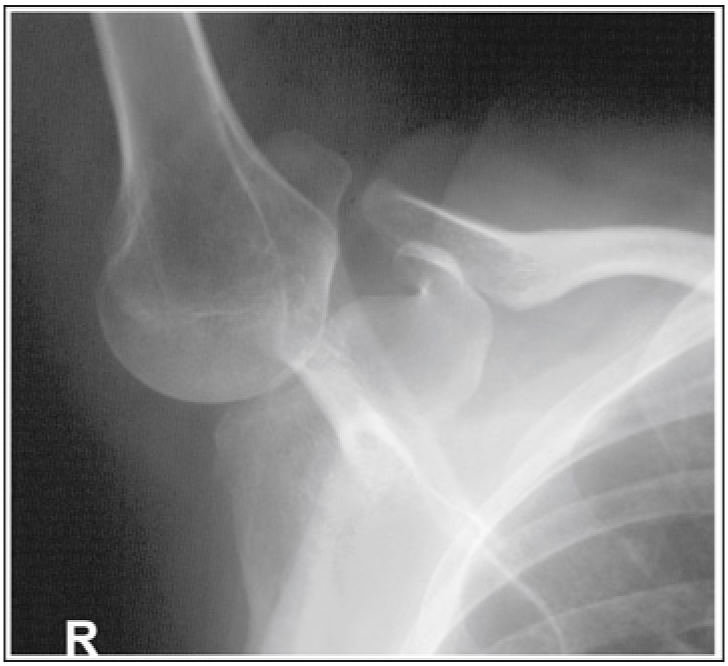


FIGURE 5.64 AP axial (Stryker) shoulder projection taken with the humerus abducted beyond vertical.

Humeral Abduction Less Than Vertical

If the CR is accurately angled, but the humerus is abducted to a position that is less than vertical for an AP axial shoulder, the posterolateral humeral head is obscured, and the humeral shaft demonstrates increased

foreshortening on the resulting projection (**Fig. 5.65**). There will also be an increase in brightness due to the increased arm thickness in this area.

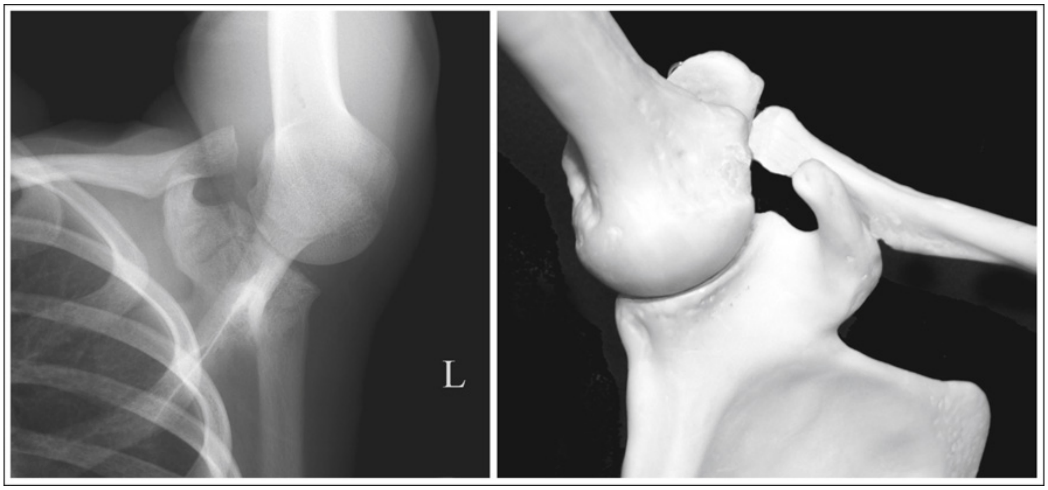


FIGURE 5.65 AP axial (Stryker) shoulder projection taken with the humerus abducted less than vertical.

Elbow Positioned Lateral to the Shoulder

When the CR is accurately angled and the humerus is accurately abducted for an AP axial shoulder, visibility of the posterolateral humeral head is also dependent on the degree of medial and lateral tilt of the humerus. If the elbow is positioned lateral to the shoulder, causing the humeral epicondyles to rotate and no longer be parallel with the IR, the posterolateral humeral head is no longer in profile, but is demonstrated on end, and the lesser tubercle appears in partial profile medially (**Fig. 5.66**). Note the large Hill-Sachs defect that is not in profile but demonstrated more on-end.

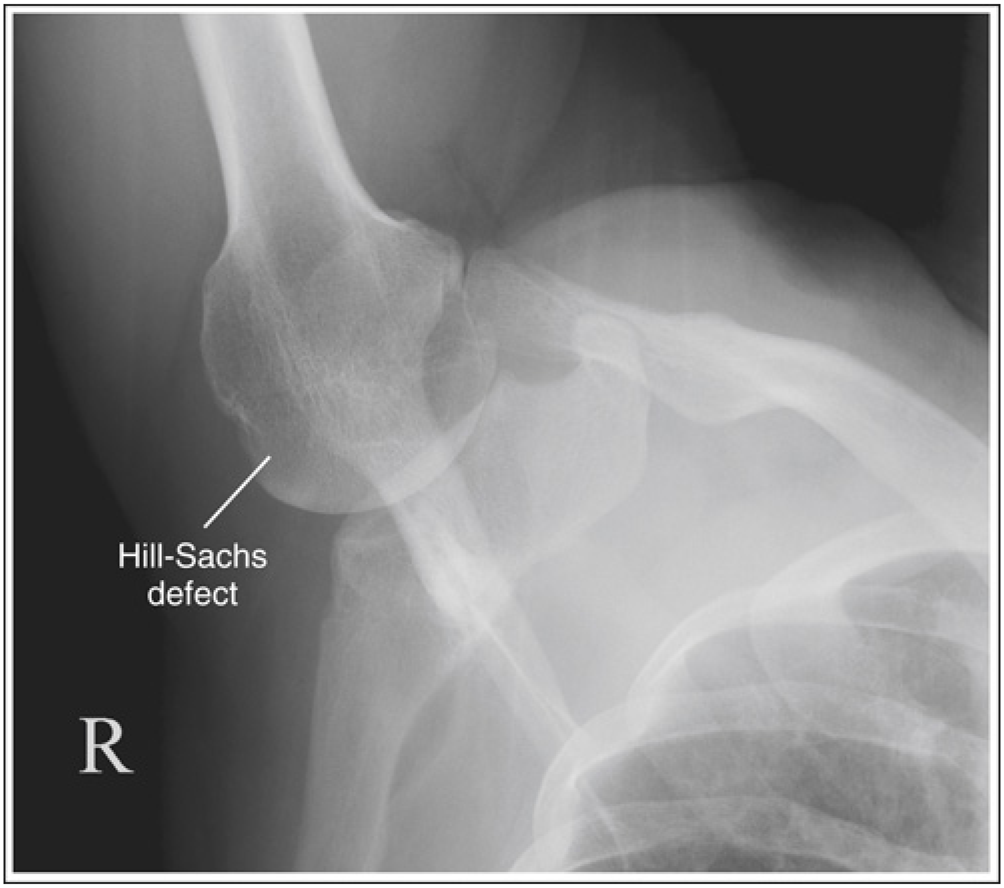


FIGURE 5.66 AP axial (Stryker) shoulder projection demonstrating a large Hill-Sachs defect and the distal humerus tilted laterally.

Elbow Positioned Medial to the Shoulder

If the elbow is positioned medial to the shoulder for an AP axial shoulder, causing the humeral epicondyles to rotate and no longer be parallel with the IR, the lesser tubercle and posterolateral humeral head is superimposed by the proximal neck, and the greater tubercle is demonstrated in profile laterally on the resulting projection (**Fig. 5.67**).

FIGURE 5.67 AP axial (Stryker) shoulder projection with the distal humerus tilted medially.

AP Axial (Stryker Notch) Shoulder Analysis Practice

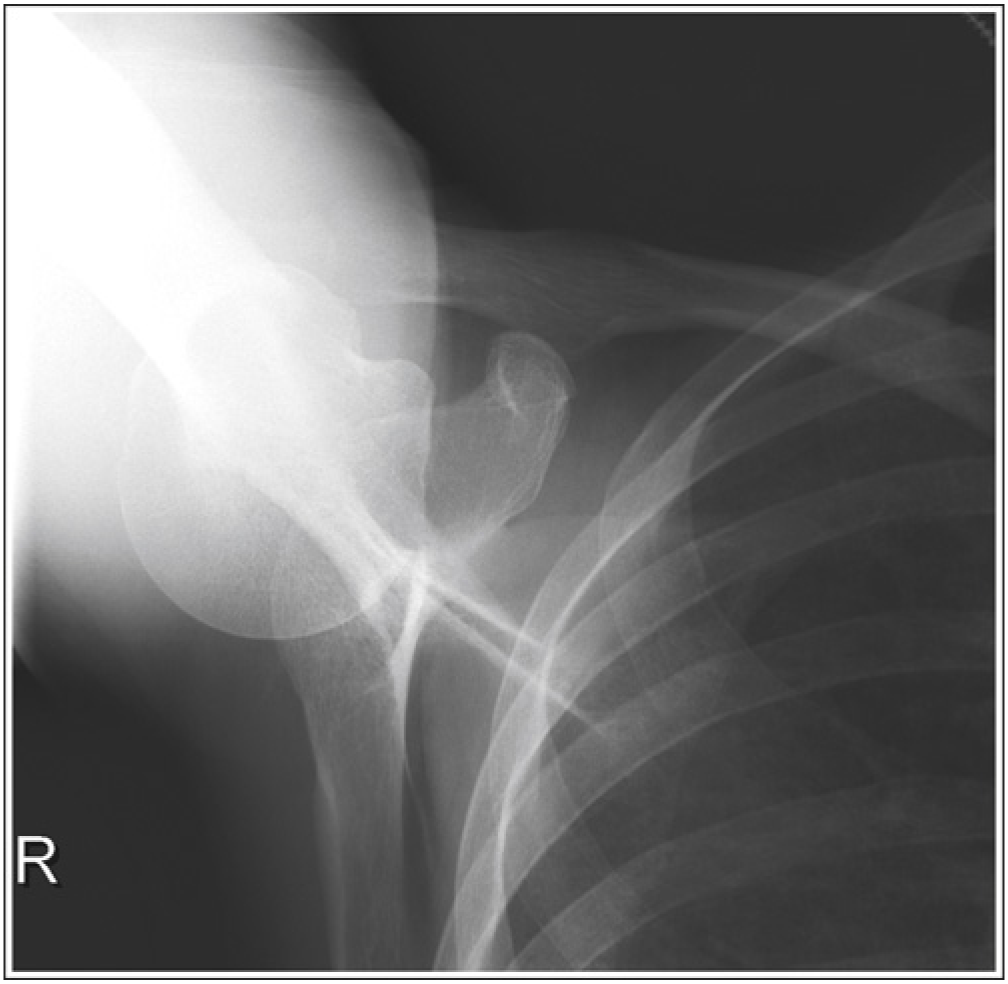


IMAGE 5.11

Analysis

The coracoid process is inferior to the clavicle. The upper thoracic vertebrae were arched upward, causing the upper midcoronal plane to tilt anteriorly or less than a 10-degree cephalic CR angle was used. The humeral shaft demonstrates excessive foreshortening. The humerus was elevated less than vertically. The lesser tubercle is demonstrated in profile and the posterior lateral humeral head is obscured. The humerus was tilted laterally.

Correction

Have patient flatten the upper thoracic vertebrae against the table and assure that a 10-degree cephalic CR angle was used; abduct the humerus to 90 degrees with the torso and align it vertically, with the humeral epicondyles parallel with the IR.

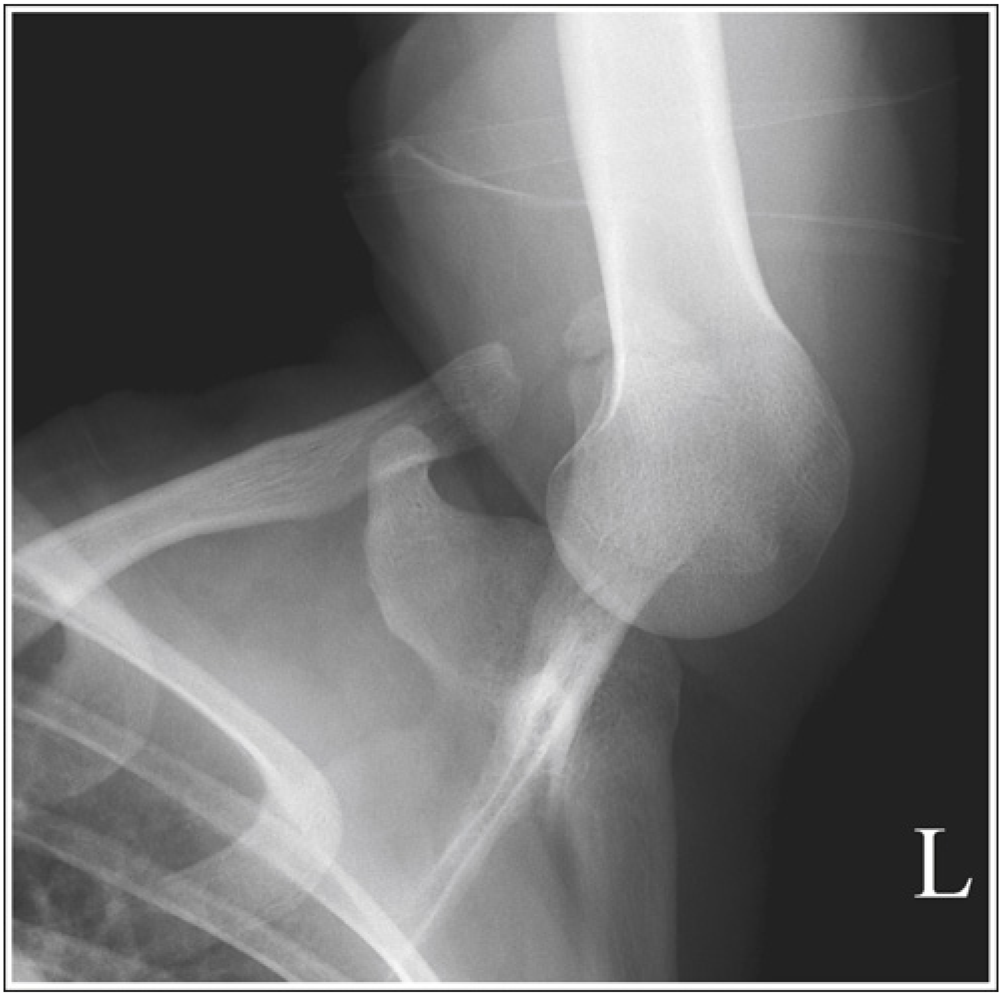


IMAGE 5.12

Analysis

The greater tubercle is demonstrated in profile laterally. The elbow was positioned medial to the shoulder.

Correction

Shift the elbow laterally until the humerus is vertical and the humeral epicondyles are parallel with the IR.

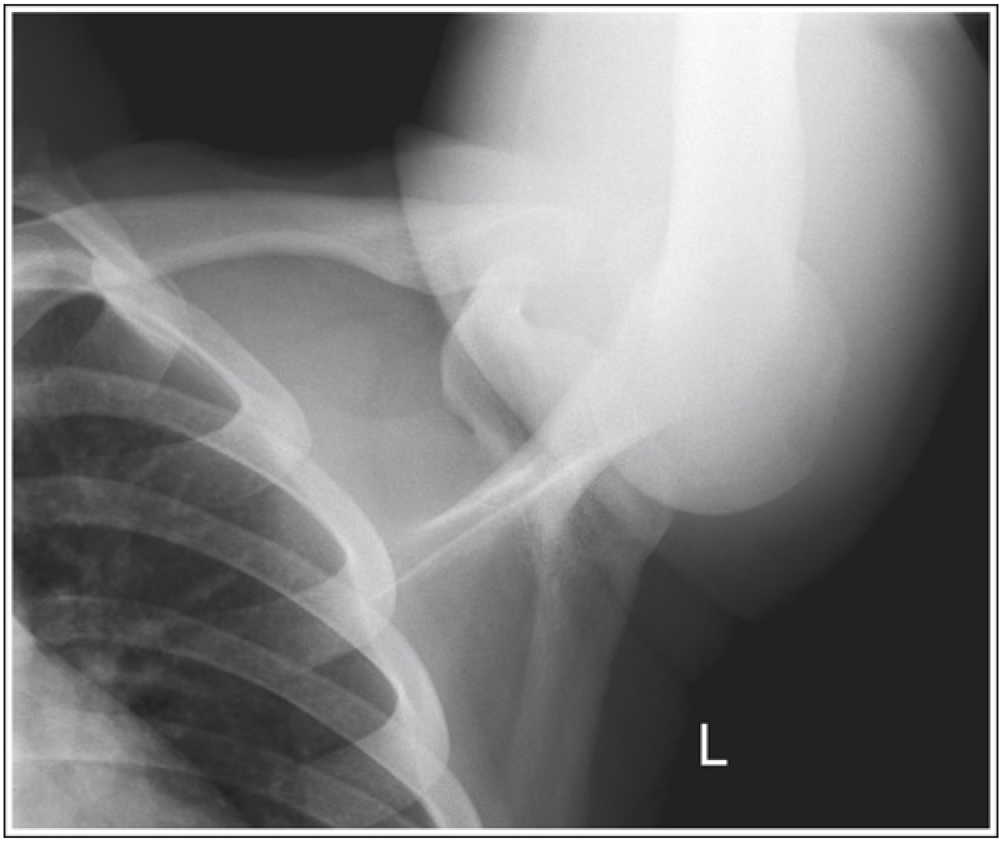


IMAGE 5.13

Analysis

The humeral shaft demonstrates increased foreshortening. The humerus was abducted to a position that was less than vertical.

Correction

Abduct the humeral shaft until it is vertical.

Supraspinatus “Outlet”: Tangential Projection (Neer Method)

See **Table 5.7** and **Figs. 5.68–5.70**.

TABLE 5.7

AC, Acromioclavicular; *CR*, central ray; *IR*, image receptor; *PA*, posteroanterior.

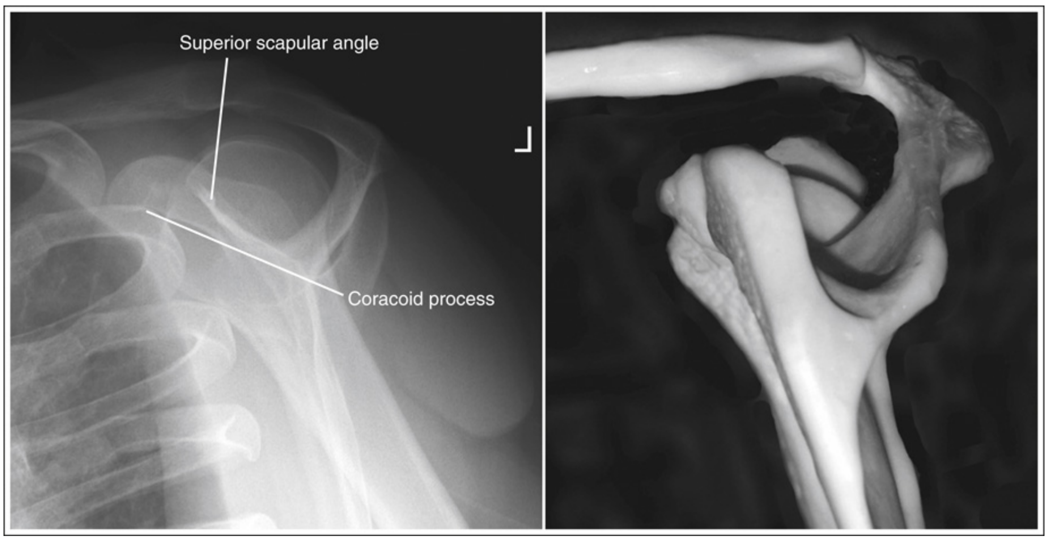


FIGURE 5.68 Tangential (outlet) shoulder projection with accurate positioning.

FIGURE 5.69 Proper tangential (outlet) shoulder projection with arm abducted.

FIGURE 5.70 Proper tangential (outlet) shoulder projection with arm dangling (nonabducted).

Exam Indication

The supraspinatus muscle runs along the supraspinatus fossa, beneath the acromion, and attaches to the greater tubercle. Narrowing of the supraspinatus outlet is caused by a variation in the shape or slope of the acromion or AC joint because of spur or osteophyte formations. This narrowing is the primary cause of shoulder impingement and rotator cuff tears. The tangential projection is taken to identify the formation of spurs or osteophytes on the inferior surfaces of the lateral clavicle and acromion process angle.

Torso and Shoulder Obliquity

The degree of torso and shoulder obliquity required to obtain a lateral scapula varies with the degree of arm abduction. When the tangential shoulder projection is obtained with the arm abducted and hand resting on the hip (see **Fig. 5.69**), the shoulder is retracted as the torso is rotated because the IR prevents the humerus from rotating with the body. This shoulder retraction causes the scapula to glide around the thoracic cavity, moving it toward the spinal column. When the scapula is in this posterior position, the torso needs to be rotated closer to a 60-degree angle to bring the scapular body to a lateral projection. When the arm is allowed to hang freely for the projection, the shoulder is not retracted, resulting in the scapular body being positioned more anteriorly and therefore requiring a 45-degree oblique angle to bring it into a lateral projection (see **Fig. 5.70**).

Insufficient Torso and Shoulder Obliquity

If the scapula does not demonstrate a Y formation and the vertebral border superimposes the thorax or is demonstrated closer to the thorax than the lateral border on a tangential shoulder projection, torso and shoulder obliquity was insufficient (**Fig. 5.71**). The glenoid cavity will move in the same direction as the lateral scapular border.

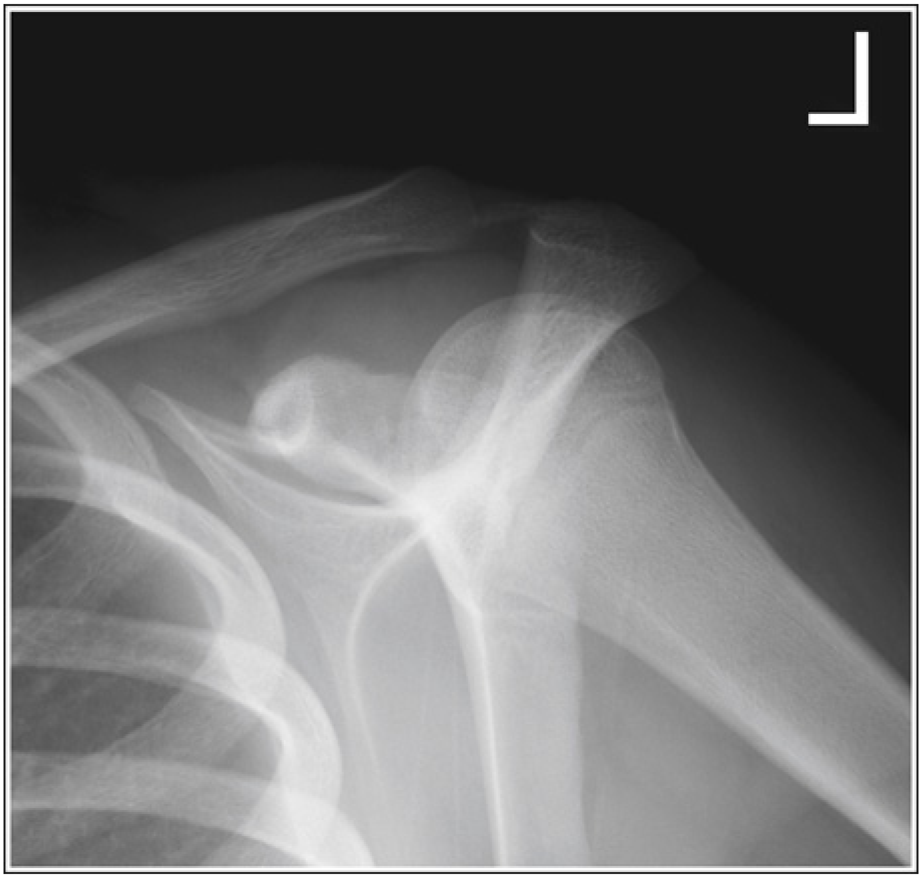


FIGURE 5.71 Tangential (outlet) shoulder projection taken with insufficient scapular obliquity.

Excessive Torso and Shoulder Obliquity

If the scapula does not demonstrate a Y formation and the lateral border is superimposed by the thorax or is positioned closer to the thorax than the vertebral border on a tangential shoulder projection, the torso and shoulder obliquity was excessive (**Fig. 5.72**).

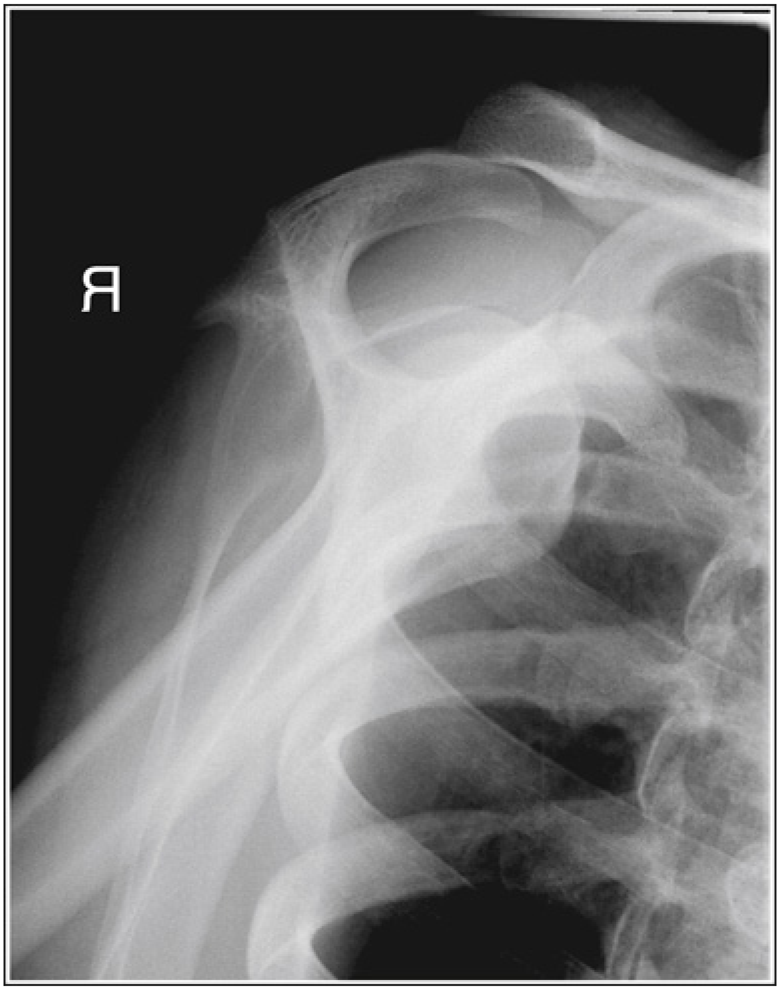


FIGURE 5.72 Tangential (outlet) shoulder projection taken with excessive scapular obliquity.

Upper Midcoronal Plane Tilted Anteriorly or Insufficient Caudal CR Angulation

If the tangential projection is taken with the upper midcoronal plane tilted anteriorly, with less than a 10- to 15-degree caudal CR angle, or with the CR centered too inferiorly, the supraspinatus outlet is narrowed, the inferior AC joint is not in profile, and the superior scapular angle is visualized at or above the clavicle on the resulting projection (**Fig. 5.73**).

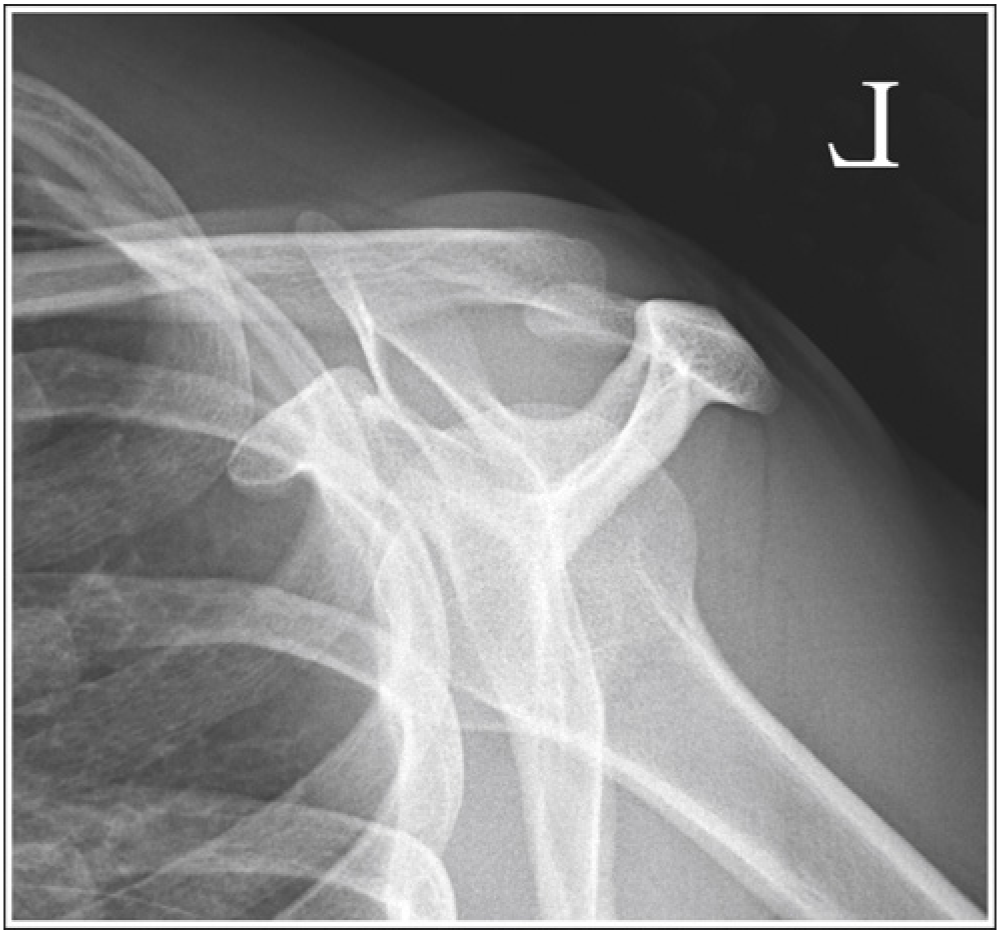


FIGURE 5.73 Tangential (outlet) shoulder projection taken without the caudal CR angulation or with the upper midcoronal plane tilted anteriorly.

Upper Midcoronal Plane Tilted Posteriorly or Excessive Caudal CR Angulation

If the tangential projection is taken with the upper midcoronal plane tilted posteriorly or with more than a 10- to 15-degree caudal CR angle, the inferior AC joint will not be in profile, and the superior scapular angle will be more than 0.5 inch (1.25 cm) inferior to the clavicle on the resulting projection.

Tangential (Outlet) Shoulder Analysis Practice

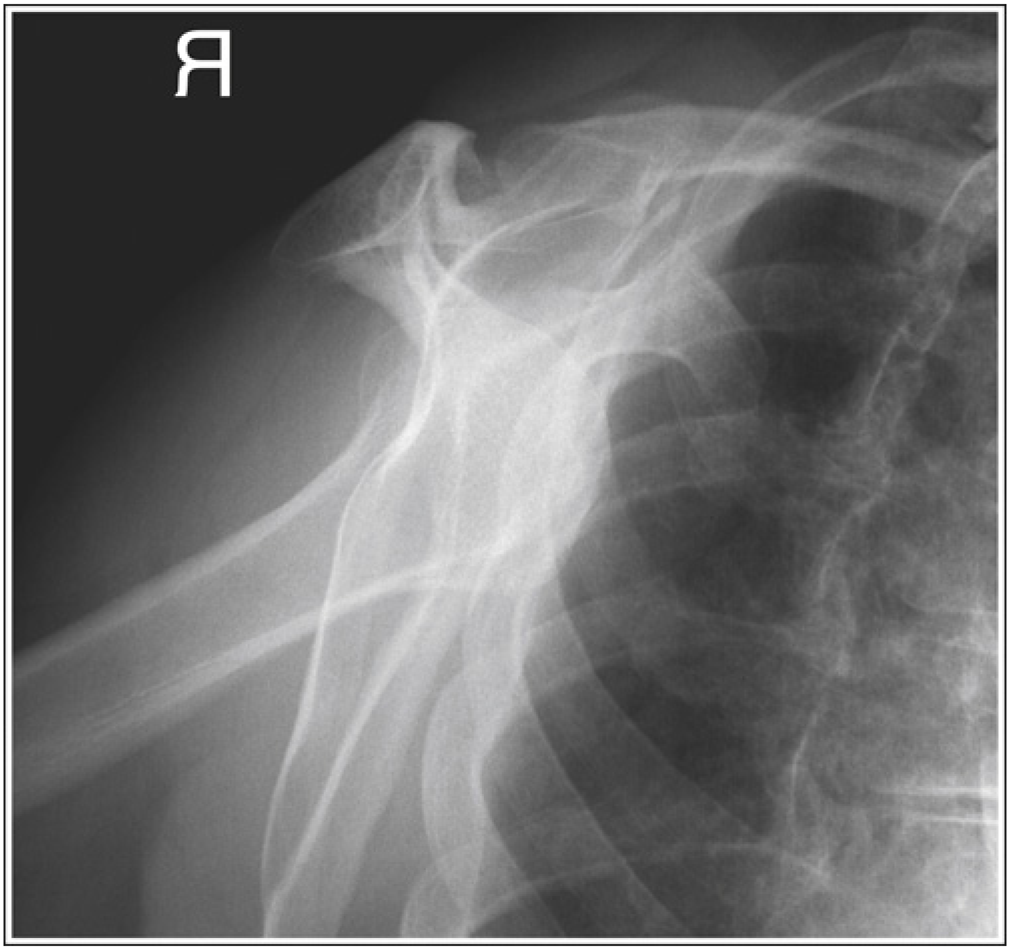


IMAGE 5.14

Analysis

The lateral and vertebral borders of the scapula are demonstrated without superimposition. The lateral border is demonstrated next to the ribs. The shoulder was overrotated. The supraspinatus outlet is closed, the superior scapular angle is seen superior to the lateral clavicle, and the inferior AC joint is not in profile. The projection was taken without the CR angled

caudally enough or with the upper midcoronal plane tilted anteriorly toward the IR.

Correction

Decrease the degree of toros rotation until the scapular borders are superimposed, ensure that the 10- to 15-degree caudal CR angle was used, and straighten the upper midcoronal plane, aligning it parallel with the IR.

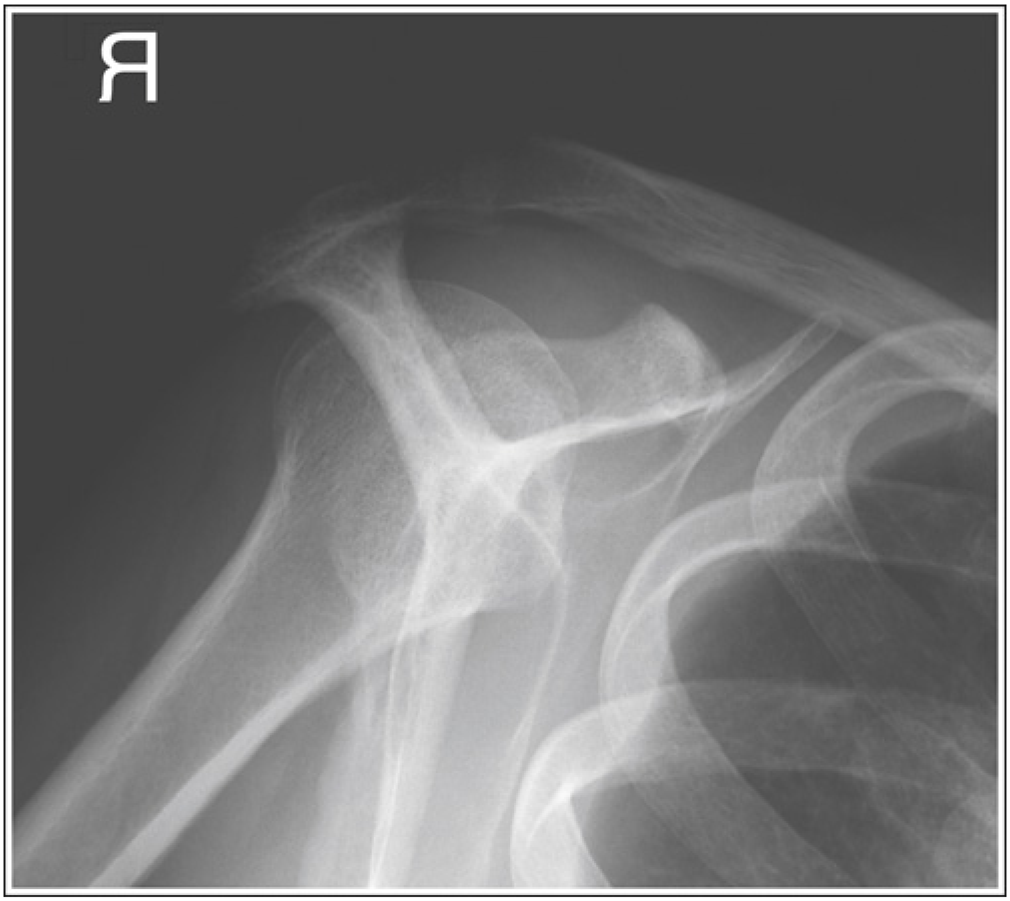


IMAGE 5.15

Analysis

The lateral and vertebral borders of the scapular are demonstrated without superimposition. The medial border is demonstrated next to the ribs. The shoulder was underrotated. The supraspinatus outlet is narrowed, the superior scapular angle is superimposing the clavicle, and the inferior AC joint is not in profile. The projection was taken without the CR angled caudally enough or with the upper midcoronal plane tilted anteriorly toward the IR.

Correction

Increase degree of torso and shoulder obliquity, ensure that the 10- to 15-degree caudal CR angle was used, and straighten the upper midcoronal plane, aligning it parallel with the IR.

Clavicle: AP Projection

See **Table 5.8** and **Figs. 5.74** and **5.75**.

TABLE 5.8

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

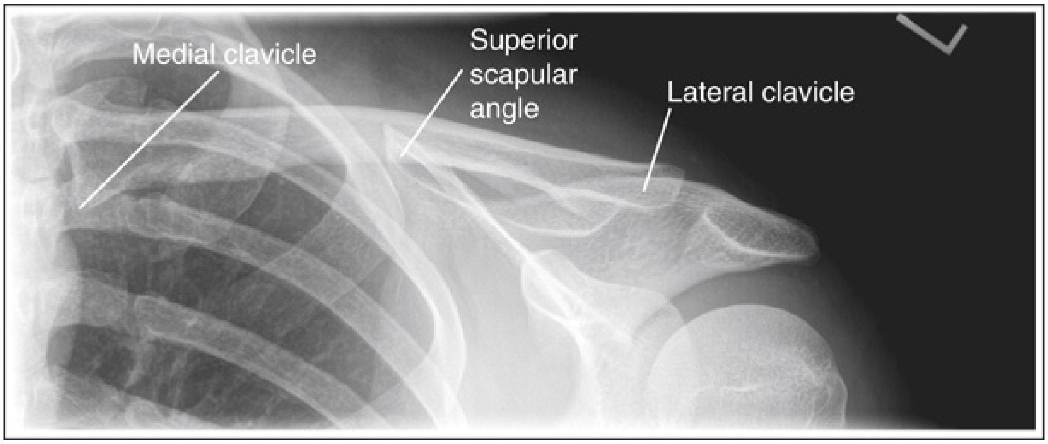


FIGURE 5.74 AP clavicular projection with accurate positioning.

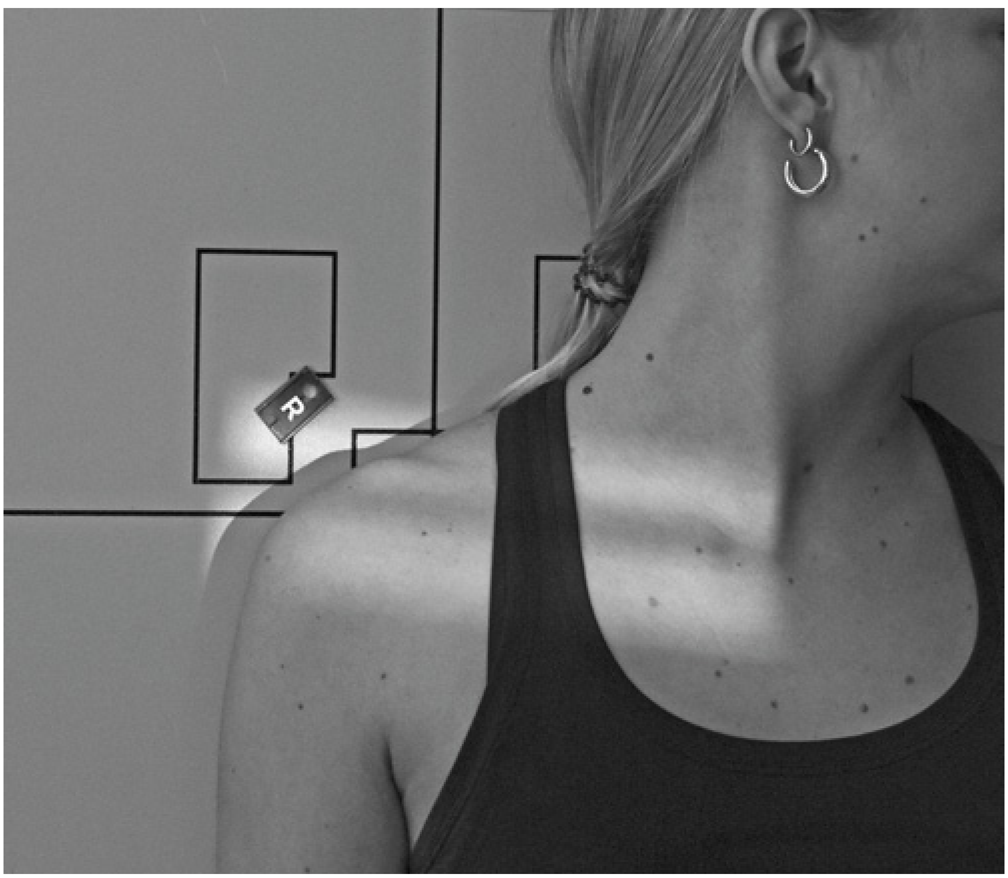


FIGURE 5.75 Proper AP clavicular positioning.

Torso Rotated Away From Affected Clavicle

Rotation and therefore longitudinal foreshortening on an AP clavicle projection is detected by evaluating the relationships of the medial clavicular end with the vertebral column. If the torso is rotated away from the affected clavicle, the medial end of the clavicle is superimposed over the vertebral column (**Fig. 5.76**).

FIGURE 5.76 AP clavicular projection taken with the patient rotated toward the unaffected shoulder.

Torso Rotated Toward Affected Clavicle

If the torso is rotated toward the affected clavicle for an AP clavicle, the medial end of the clavicle draws away from the vertebral column and the clavicle is longitudinally foreshortened on the resulting projection (**Fig. 5.77**).

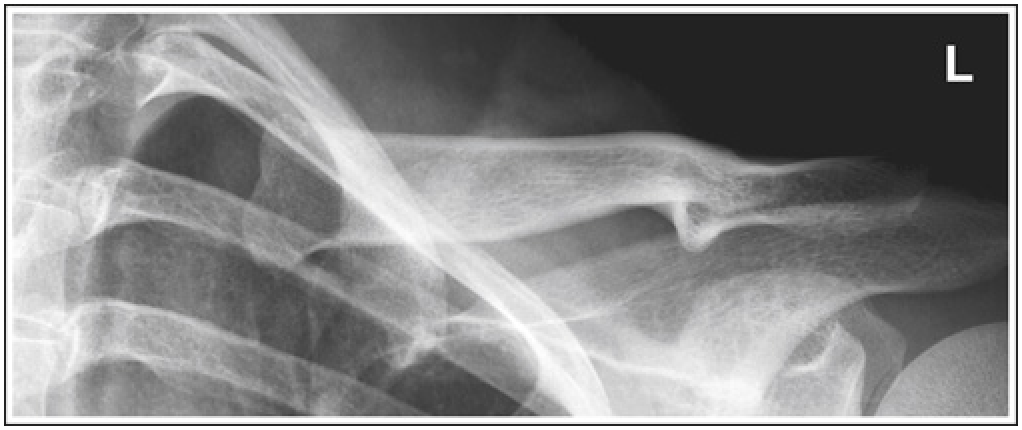


FIGURE 5.77 AP clavicular projection taken with the patient rotated toward the affected shoulder.

Upper Midcoronal Plane Tilted Anteriorly

If the upper midcoronal plane is tilted anteriorly for an AP clavicle, the superior scapular angle will be demonstrated superior to the clavicle on the resulting projection (**Fig. 5.78**).

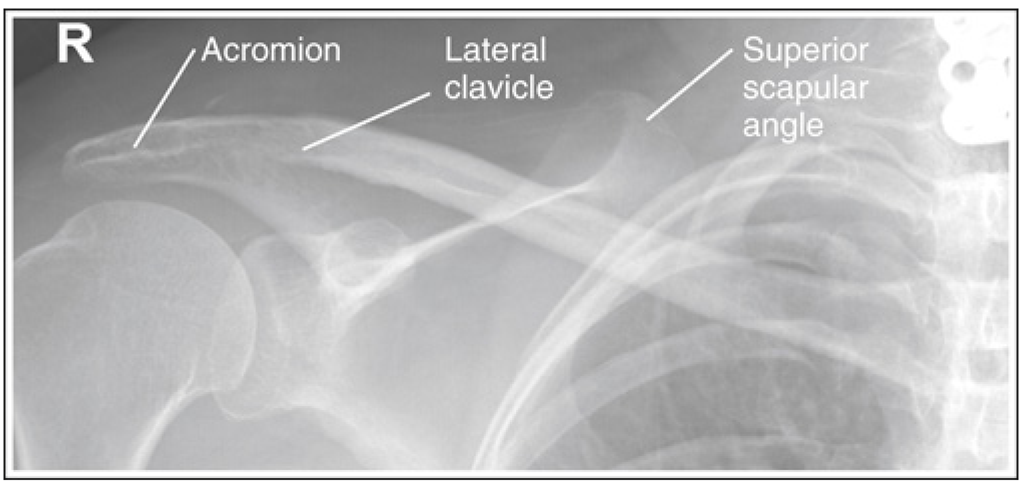


FIGURE 5.78 AP clavicular projection taken with the upper midcoronal plane tilted anteriorly.

Upper Midcoronal Plane Tilted Posteriorly

If the upper midcoronal plane is tilted posteriorly for an AP clavicle, the superior scapular angle is shown inferior to the clavicle on the resulting projection (**Fig. 5.79**).

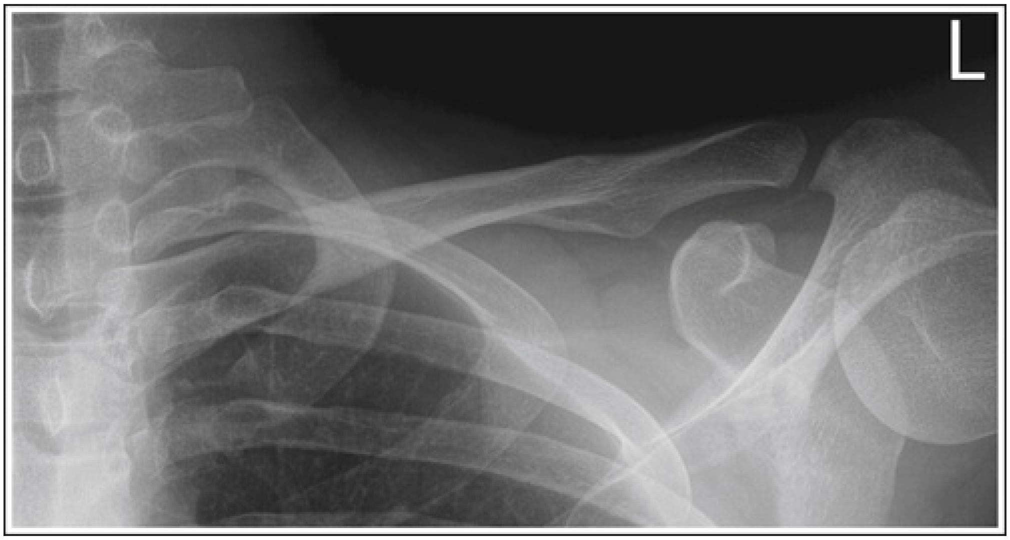


FIGURE 5.79 AP clavicular projection taken with the upper midcoronal plane tilted posteriorly.

AP Clavicle Analysis Practice

IMAGE 5.16

Analysis

The medial end of the clavicle is drawn away from the lateral edge of the vertebral column. The torso was rotated toward the affected shoulder.

Correction

Rotate the torso away from the affected shoulder until the shoulders are positioned at equal distances from the IR.

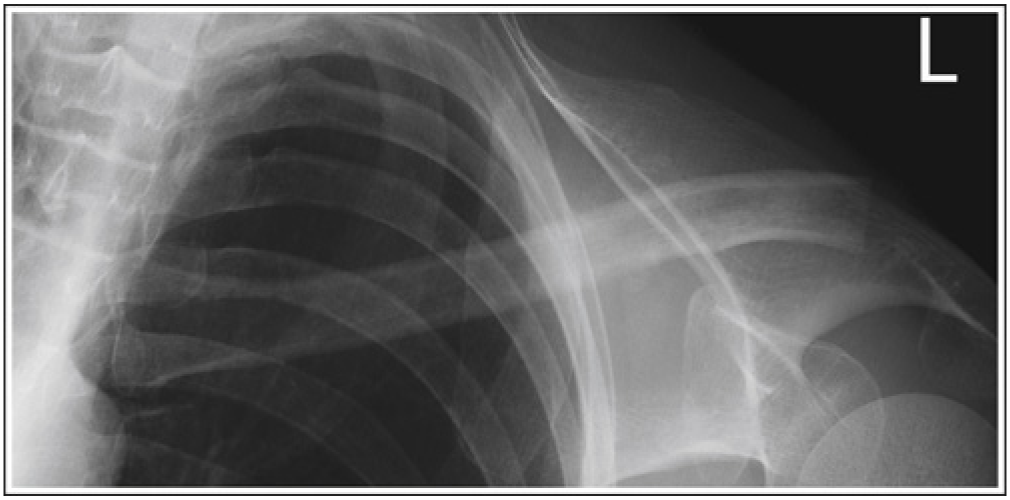


IMAGE 5.17

Analysis

The superior scapular angle is projected superiorly to the midclavicle. The upper midcoronal plane was tilted anteriorly.

Correction

Straighten the upper thoracic vertebrae until the midcoronal plane is aligned parallel with the IR.

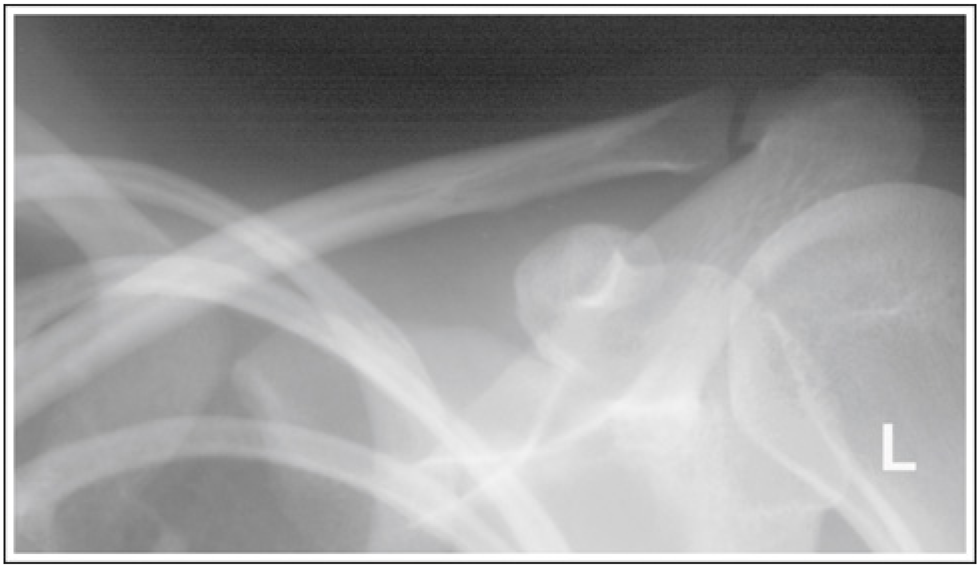


IMAGE 5.18

Analysis

The superior scapular angle is seen inferior to the midclavicle. The upper midcoronal plane was tilted posteriorly. The medial clavicular is not included on the projection. The CR was positioned too laterally.

Correction

Straighten the upper thoracic vertebrae until the midcoronal plane is aligned parallel with the IR, center the CR approximately 1 inch (2.5 cm) medially, and open collimation enough to include the medial end of the clavicle.

Clavicle: AP Axial Projection (Lordotic Position)

See **Table 5.9** and **Figs. 5.80** and **5.81**.

TABLE 5.9

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

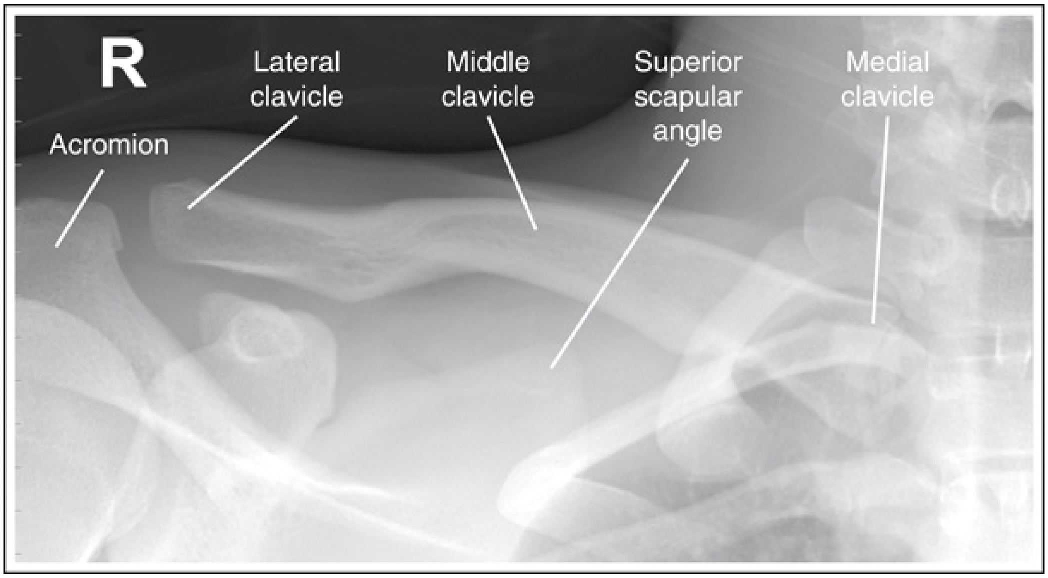


FIGURE 5.80 AP axial clavicular projection with accurate positioning.

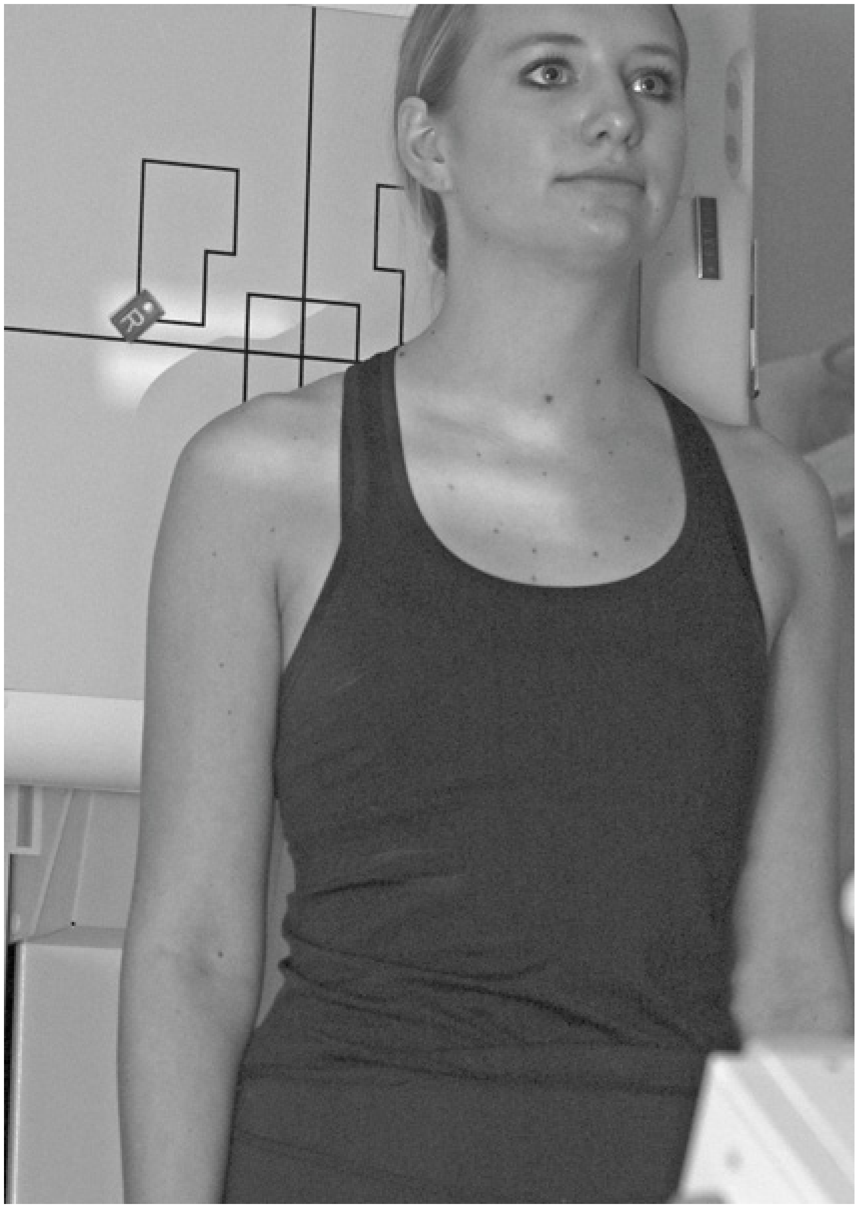


FIGURE 5.81 Proper AP axial clavicular positioning.

Torso Rotation

If the torso is rotated toward the unaffected clavicle for an AP axial clavicle, the medial end of the clavicle superimposes the vertebral column on the resulting projection (see **Fig. 5.76**). If the torso is rotated toward the

affected clavicle for an AP axial clavicle, the medial end of the clavicle is drawn away from the vertebral column and the clavicle is longitudinally foreshortened on the resulting projection (see **Fig. 5.77**). Rotation on the AP and AP axial clavicle projections are similar, but the clavicle on the AP axial projection would be situated more superiorly on the thorax.

CR Angulation

A 15- to 30-degree cephalic CR angle is used on the AP axial projection of the clavicle to project more of the clavicle superior to the thorax region and to demonstrate the degree of fracture displacement, when present. Even though the amount of angulation used may vary among radiology departments, all projections result in superior movement of the clavicle. The larger the angle, the more superiorly the clavicle is projected. Ideally, because 80% of clavicle fractures occur at the middle third and 15% at the lateral third, the CR should be angled enough to project the lateral and middle thirds of the clavicle superior to the thorax and scapula. Compare the projections in **Figs. 5.82** and **5.83**, and note how an increase in cephalic angulation has projected the lateral and middle thirds of the clavicle above the scapula. The clavicle fracture demonstrated on these projections is obvious, but a subtle nondisplaced fracture could be obscured by the scapular structures if an AP axial projection were not included in the examination.

FIGURE 5.82 AP clavicular projection demonstrating a fractured clavicle.

FIGURE 5.83 AP axial clavicular projection demonstrating a fractured clavicle.

AP Axial Clavicle Analysis Practice

IMAGE 5.19

Analysis

The medial clavicle is superimposing over the third rib and the lateral clavicle is not superior to the acromion. The CR was insufficiently angled.

Correction

Increase the degree of cephalic CR angulation.

AC Joint: AP Projection

See **Table 5.10** and **Figs. 5.84–5.87**.

TABLE 5.10

AC, Acromioclavicular; *AP*, anteroposterior; *CR*, central ray; *IR*, image receptor.

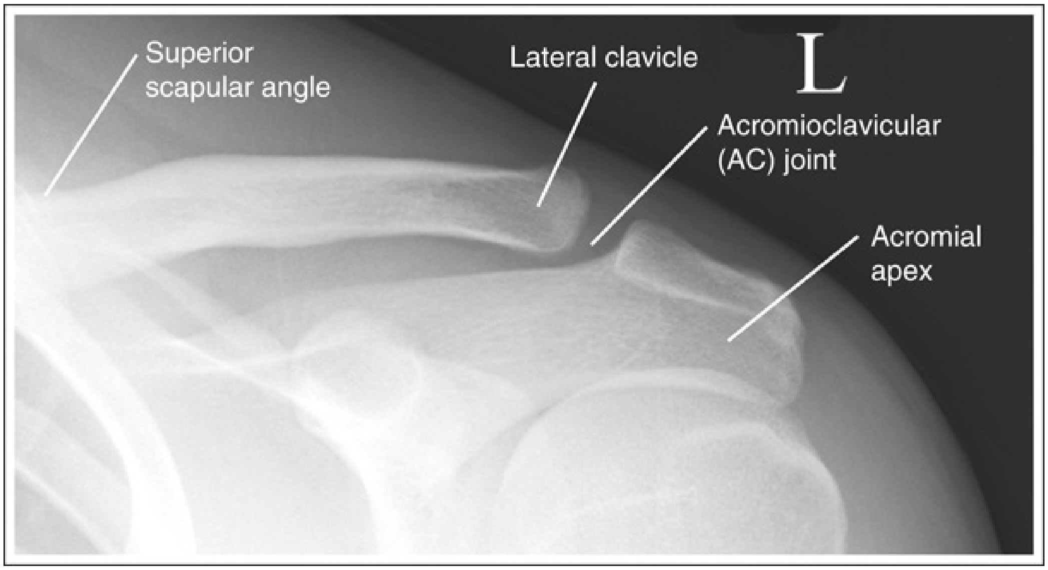


FIGURE 5.84 AP acromioclavicular joint projection (without weights) with accurate positioning.

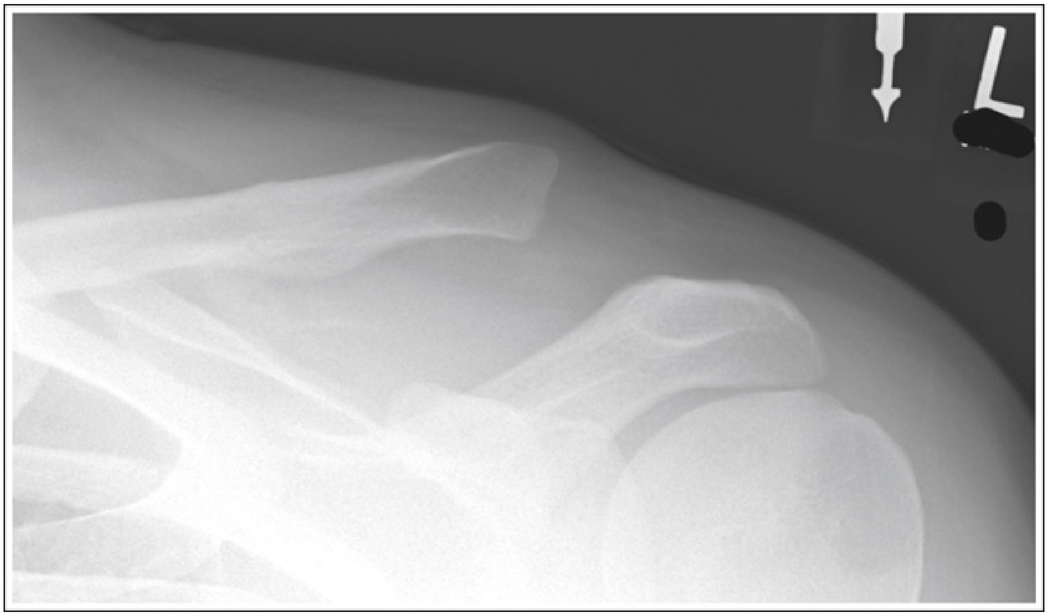


FIGURE 5.85 AP acromioclavicular joint projection (with weights) with accurate positioning.

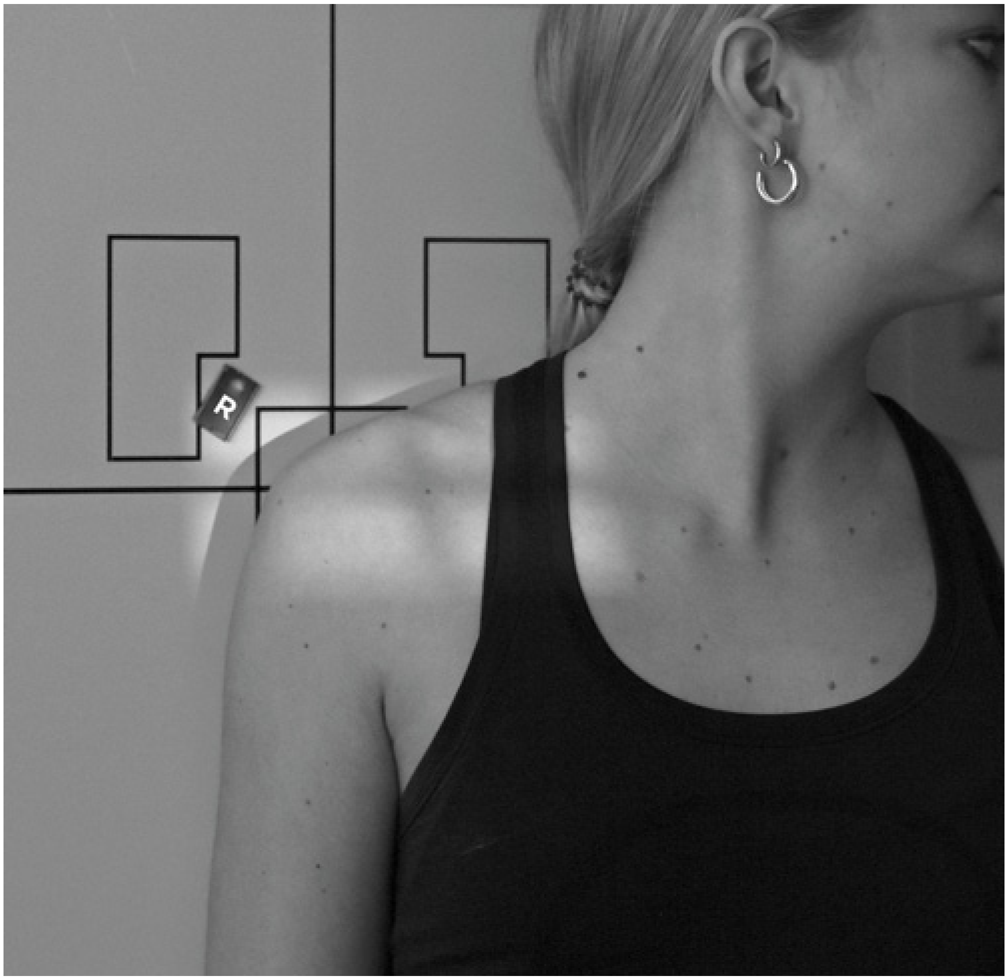


FIGURE 5.86 Proper AP acromioclavicular joint positioning (without weights).

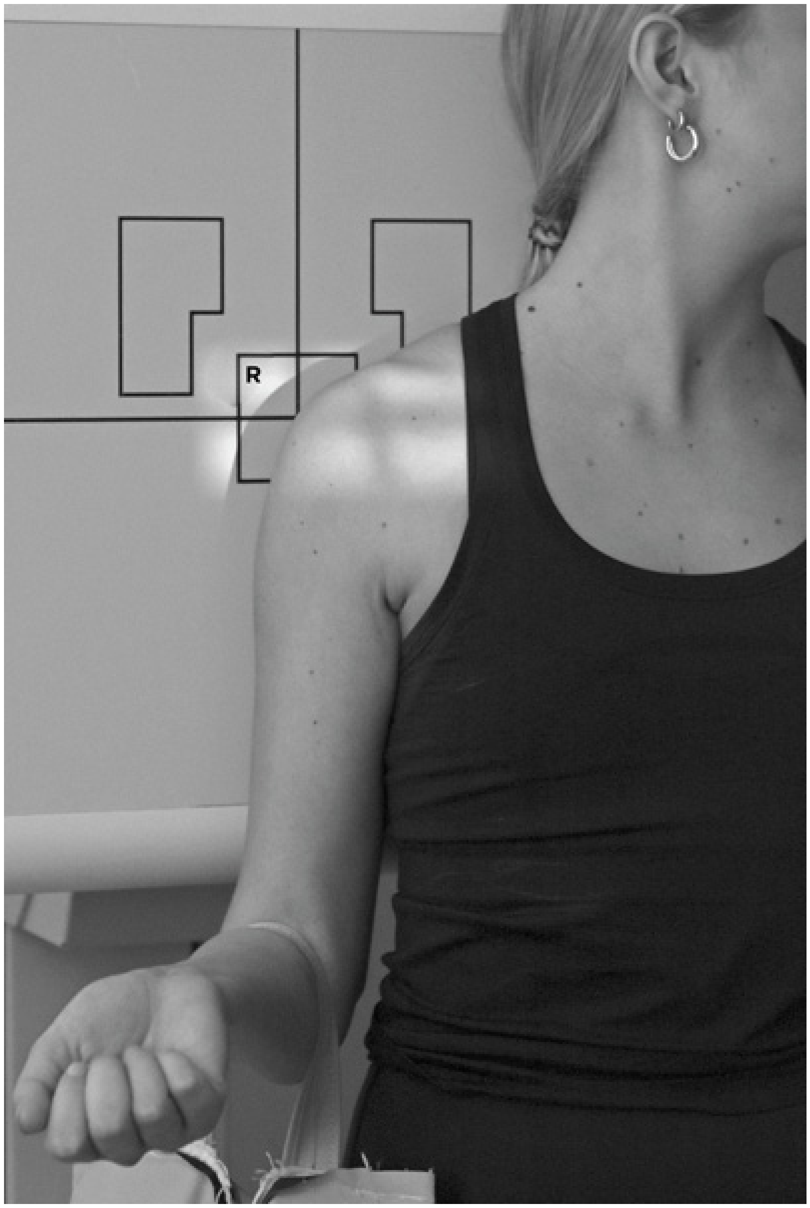


FIGURE 5.87 Proper AP acromioclavicular joint positioning (with weights).

Exam Indication

To evaluate the AC joint for possible injury to the AC ligament, which extends between the lateral clavicular end and the acromion process, the AP projection is taken first without weights. Then a second AP projection is

taken with the patient holding 5- to 8-lb weights (see **Figs. 5.86** and **5.87**). If injury to the AC ligament has occurred, the AC joint space is wider on the weight-bearing projection than on the projection taken without weights.

Weight-Bearing Projection

For the weight-bearing projection, equal weights should be attached to the arms, regardless of whether the examination is unilateral (one side) or bilateral (both sides), keeping the shoulders on the same transverse plane. Attach the weights to the wrists or slide them onto the forearms after the elbows are flexed to 90 degrees, and instruct the patient to allow the weights to depress the shoulders.

Torso Rotated Toward Affected AC Joint

If the torso was rotated toward the affected AC joint for an AP AC joint, the lateral end of the clavicle and the acromion apex are rotated out of profile, resulting in a narrowed or closed AC joint on the resulting projection. The thoracic cavity also moves toward the scapular body, increasing the amount of scapular body superimposition (**Fig. 5.88**, right shoulder).

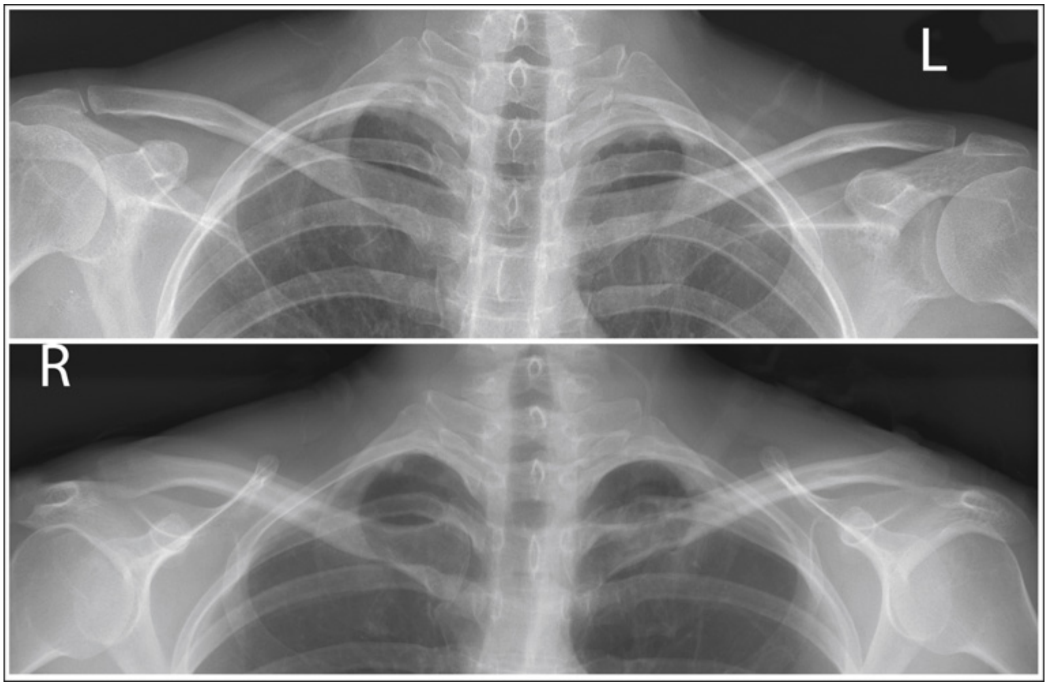


FIGURE 5.88 Bilateral AP acromioclavicular joint projections with and without rotation.

Torso Rotated Away From Affected AC Joint

If the torso is rotated away from the affected AC joint for an AP AC joint, the lateral end of the clavicle and the acromion apex demonstrate a slightly greater AC joint space with only a small amount of rotation and may be closed with a greater degree of rotation on the resulting projection. The scapular body demonstrates decreased thoracic cavity superimposition (see **Fig. 5.88**, left shoulder).

Upper Midcoronal Plane Tilted Anteriorly

If the upper midcoronal plane is tilted anteriorly for an AP AC joint, the lateral clavicle will demonstrate increased acromion process superimposition and the superior scapular angle will be demonstrated superior to the clavicle on the resulting projection (**Fig. 5.89**).

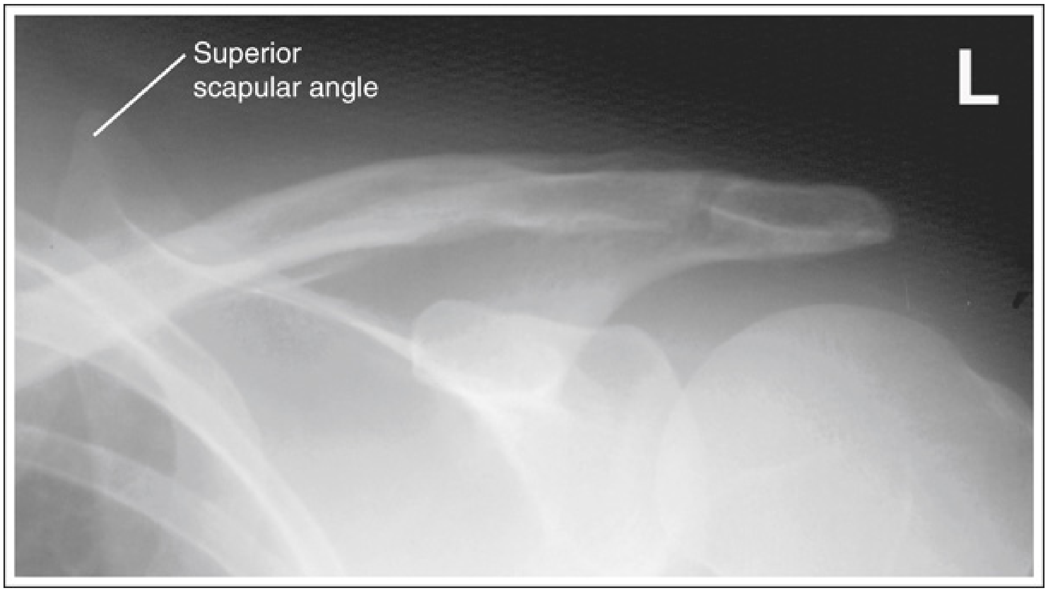


FIGURE 5.89 AP acromioclavicular joint projection taken with the upper midcoronal plane tilted anteriorly.

Upper Midcoronal Plane Tilted Posteriorly

If the upper midcoronal plane is tilted posteriorly for an AP AC joint, the lateral clavicle will demonstrate decreased acromion process superimposition and the superior scapular angle will be visible inferior to the clavicle on the resulting projection (**Fig. 5.90**).

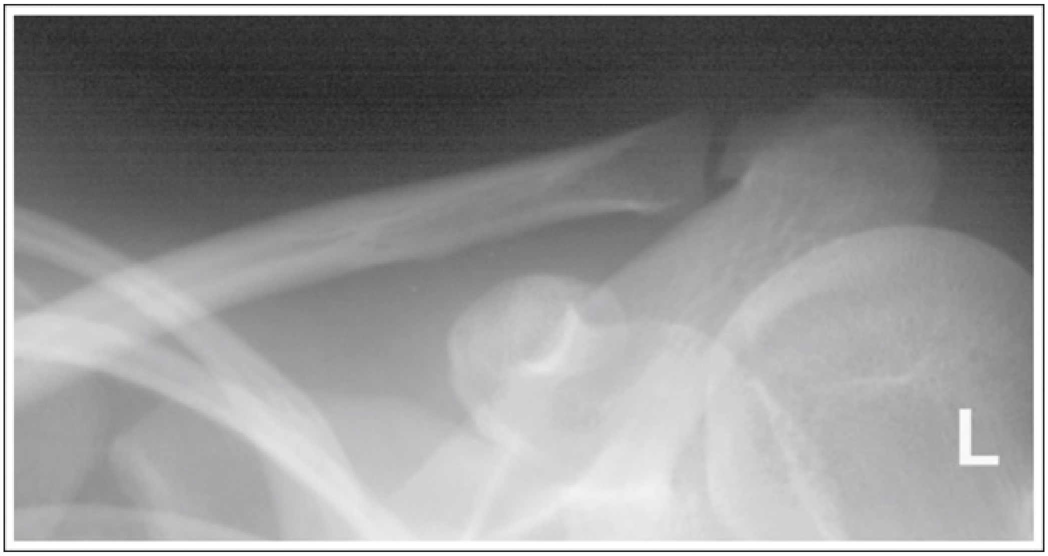


FIGURE 5.90 AP acromioclavicular joint projection taken with the upper midcoronal plane tilted posteriorly.

CR Centering

Because the shoulders are depressed when weights are used, the AC joint moves inferiorly when the patient is given weights for the second exposure. Repalpate for the AC joint on this projection to ensure that the CR is centered at the same location for both without and with weight projections. Failure to center in the same location for both projections may result in a false separation reading as the x-ray beam divergence transverses the AC joint differently. Compare **Figs. 5.91** and **5.92**, which are projections of the same patient, taken without weights and with weights, respectively. Because the CR was not centered in the same location, it is uncertain whether the separation demonstrated on the weight-bearing projection is a result of ligament injury or poor CR centering. The AC joint is located by palpating along the clavicle until the most lateral tip is reached, and then moving about 0.5 inch (1 cm) inferiorly.

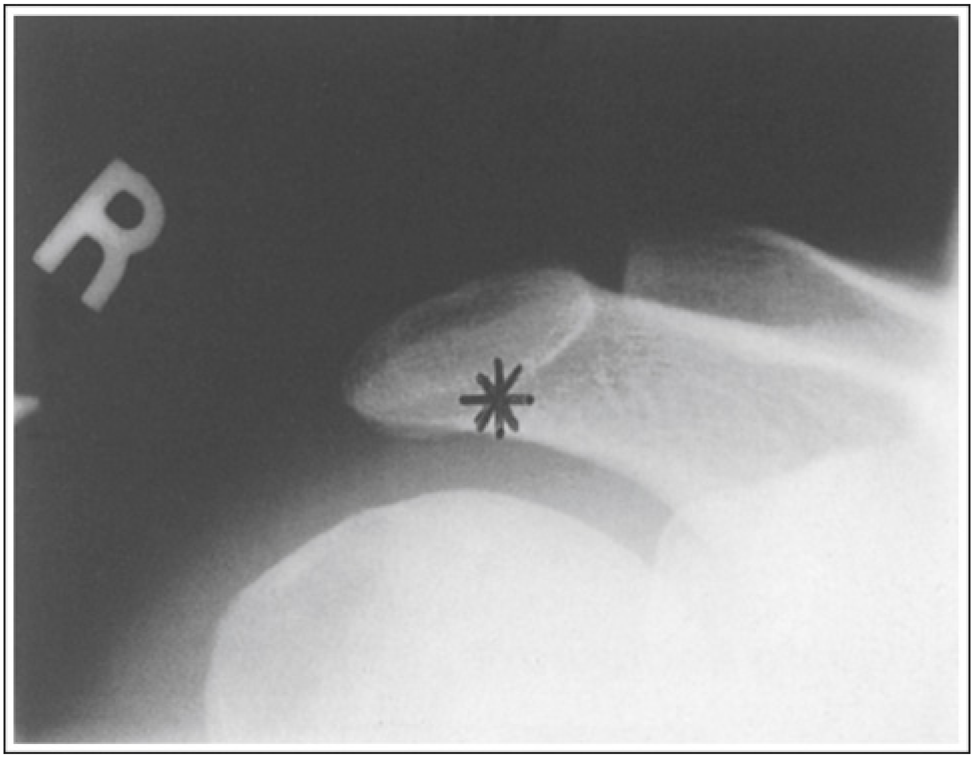


FIGURE 5.91 AP acromioclavicular joint projection taken without weights and showing good centering. *Star* indicates location of CR.

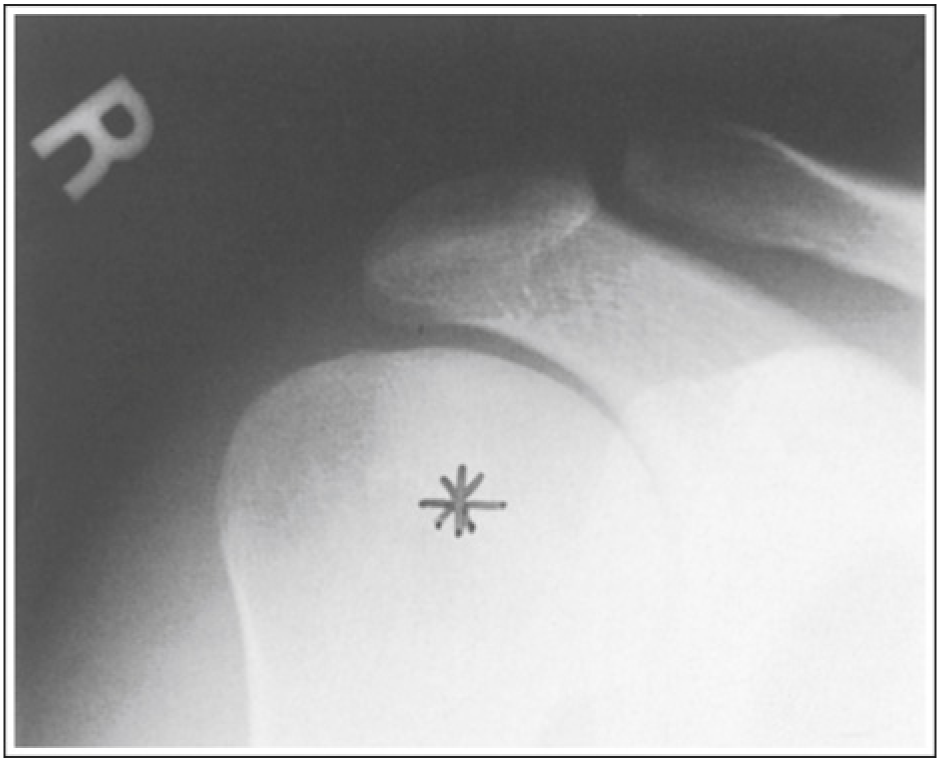


FIGURE 5.92 AP acromioclavicular joint projection taken with weights and showing poor centering. *Star* indicates location of CR.

Bilateral AC Joint Projection

Some facilities obtain bilateral projections of the AC joint as a routine. For this, place the patient in an upright AP projection with shoulders at equal distance to the upright IR and the midcoronal plane vertical. Center the midsagittal plane to the center of the IR and then center a perpendicular CR to the midsagittal plane at a level 1-inch (2.5 cm) superior to the jugular notch. Open the longitudinally collimated field to approximately a 5-inch (10-cm) field size and transversely collimate the full IR length. Make an exposure without weights and an exposure with weights. The unilateral AC joint method is recommended over this bilateral because it reduces exposure to the thyroid and uses less diverged x-rays to record the AC

joints. If the bilateral method is used, a long 72-inch (183 cm) SID is used to reduce magnification and allow both joints to fit on a single exposure (**Fig. 5.93**).

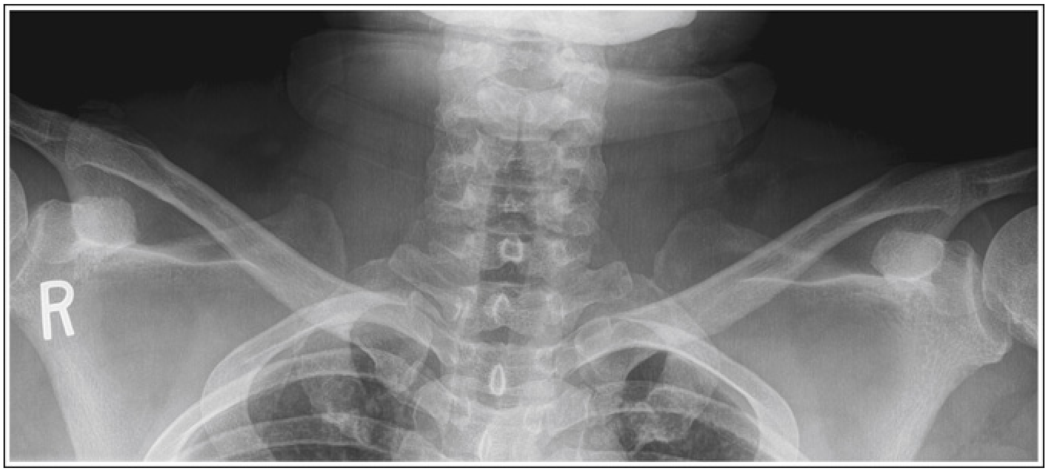


FIGURE 5.93 Bilateral AP acromioclavicular joint projection.

Scapula: AP Projection

See **Table 5.11** and **Figs. 5.94** and **5.95**.

TABLE 5.11

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

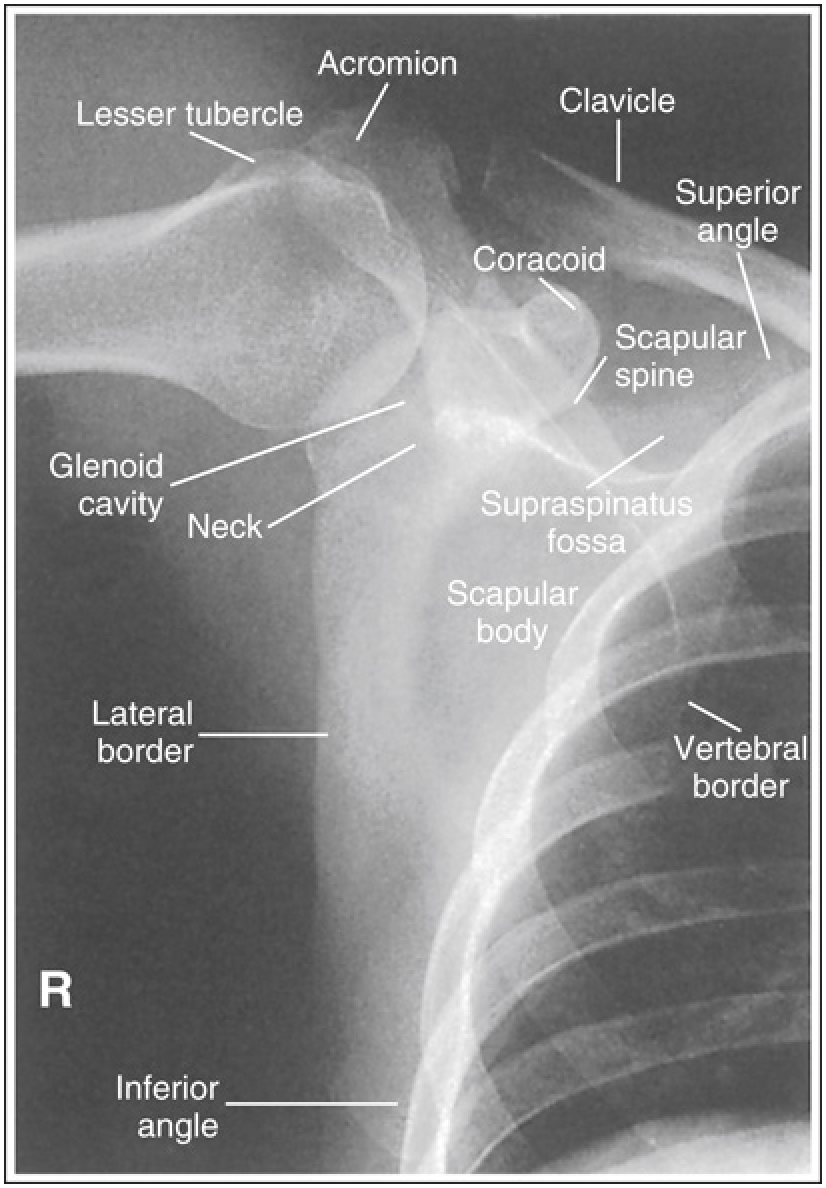


FIGURE 5.94 AP scapular projection with accurate positioning.

FIGURE 5.95 Proper AP scapular positioning.

Humeral Abduction

Abduction of the humerus is accomplished by combined movements of the shoulder joint and rotation of the scapula around the thoracic cage. The ratio of movement in these two articulations is two parts glenohumeral to one part scapulothoracic. When the arm is abducted, the lateral scapula is drawn from beneath the thoracic cavity and the glenoid cavity moves superiorly. Because the first 60 degrees of humeral abduction involves

primarily movement of the glenohumeral joint without accompanying scapular movement, it takes at least 90 degrees of humeral abduction to demonstrate the entire lateral border of the scapula without thoracic cavity superimposition, and the supraspinatus fossa and superior angle without clavicle superimposition. With less than 60 degrees of humeral abduction, the inferolateral border of the scapula is superimposed by the thoracic cavity and the clavicle is superimposed over the superior scapular angle (**Fig. 5.96**).

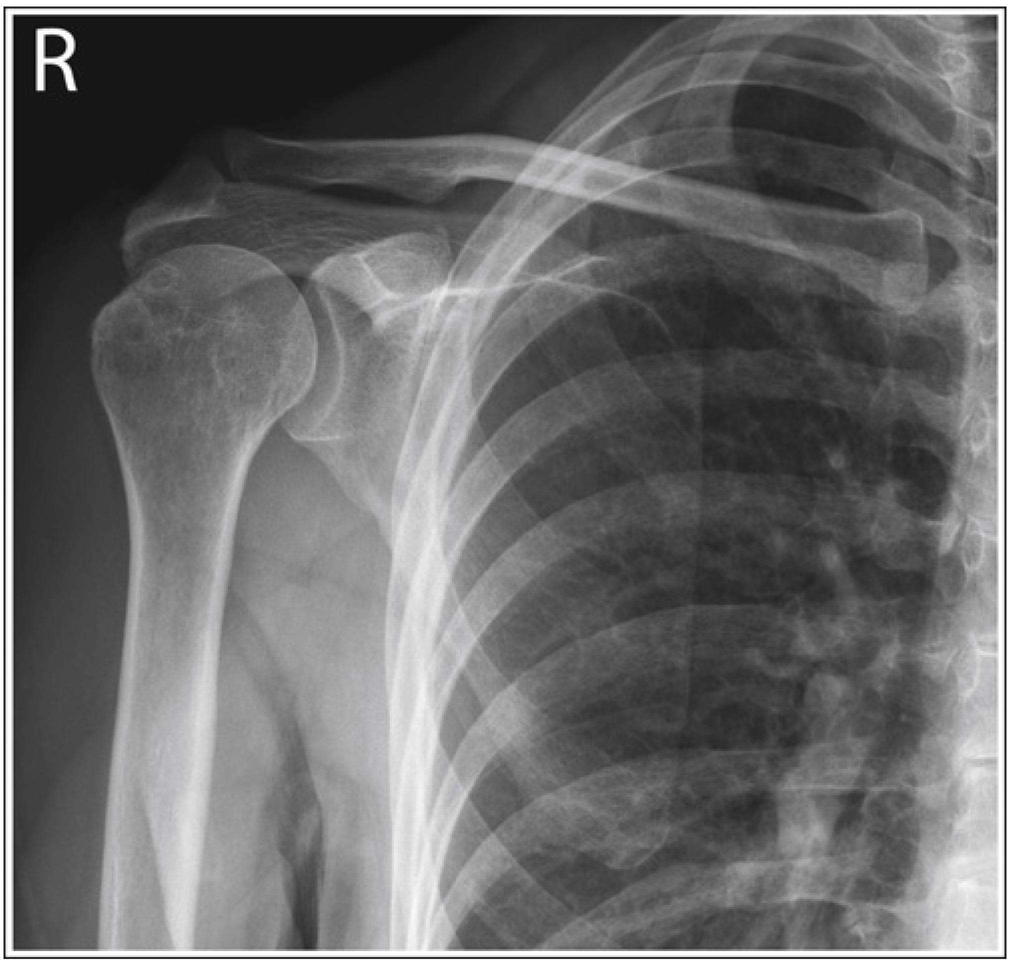


FIGURE 5.96 AP scapular projection taken without abduction.

Shoulder Retraction

In an AP scapula projection with the affected arm placed against the side, the scapular body is placed at a 35- to 45-degree angle with the IR. This positioning results in the projection demonstrating transverse foreshortening of the scapular body. To reduce this transverse foreshortening and better visualize the scapular body, the projection is taken with the patient supine, the humerus is abducted, the elbow is flexed, and the hand is supinated by rotating the arm externally (**Fig. 5.97**). The humeral abduction causes the scapula to glide around the thoracic surface, moving the inferior scapular angle and lateral scapular body from beneath the thorax. The elbow flexion and hand supination cause the shoulder to retract by placing pressure on the lateral aspect of the scapular body that will result in it moving posteriorly and the scapular body foreshortening to decrease. To take advantage of gravity and obtain maximum shoulder retraction, the projection is taken with the patient in a supine position. Poor retraction of the shoulder is identified by evaluating the foreshortening of the scapular body and the degree of glenoid cavity visualization. If the arm is not sufficiently abducted and the shoulder retracted, the scapular body demonstrates excessive foreshortening and the glenoid cavity is demonstrated somewhat on end (see **Fig. 5.97**).

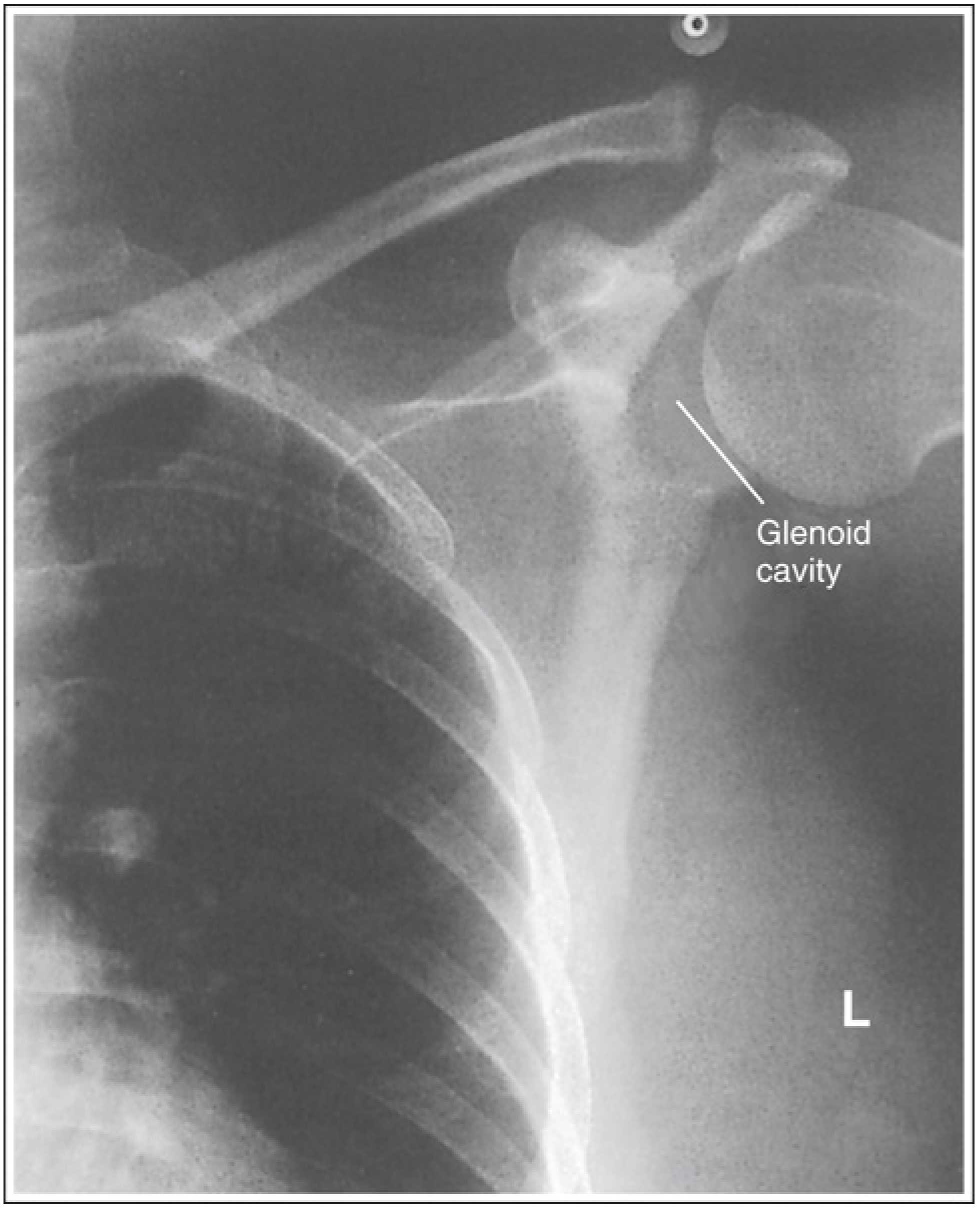


FIGURE 5.97 AP scapular projection taken without adequate shoulder retraction.

Upper Midcoronal Plane Tilting

Longitudinal foreshortening of the scapular body is caused by poor midcoronal plane positioning and may result when the AP scapular projection is taken with the patient in the upright position or when the

patient is kyphotic. Foreshortening is prevented by straightening the upper thoracic vertebrae and positioning the midcoronal plane parallel with the IR. A longitudinally foreshortened scapula can be identified on an AP scapular projection that has the arm adequately abducted when the superior scapular angle is more or less than 0.25 inch (0.6 cm) inferior to the clavicle. When the superior scapular angle is demonstrated less than 0.25 inch (0.6 cm) from the clavicle, the upper midcoronal plane was tilted anteriorly. When the superior scapular angle appears more than 0.25 inch (0.6 cm) inferior to the clavicle, the upper midcoronal plane was tilted posteriorly.

Respiration

Although the AP thickness is approximately the same across the entire scapula, the overall brightness is not uniform. On AP scapular projections, the medial portion of the scapula, which is superimposed by the thoracic cavity, demonstrates less brightness than the lateral scapula, which is superimposed by the soft tissue of the shoulder girdle. This brightness difference is a result of the difference in atomic density that exists between the air-filled thoracic cavity and the bony shoulder structures. The thoracic cavity is largely composed of air, which contains very few atoms in a given area, whereas the shoulder structures contain a higher concentration of atoms. As the radiation goes through the body, fewer photons are absorbed in the thoracic cavity than in the shoulder girdle. Taking the exposure on expiration can help increase the contrast resolution in the portion of the scapula that is superimposed by the thoracic cavity by reducing the air and slightly compressing the tissue in this area.

Positioning for Trauma

Trauma patients often experience great pain with arm abduction. Because of this pain, the abduction movement may take place almost entirely at the glenohumeral articulation, instead of involving the combined movements of the glenohumeral and scapulothoracic articulations. When the scapulothoracic articulation is not involved with the movement of humeral abduction, the inferolateral border and inferior angle of the scapula may remain superimposed by the thoracic cavity, and the supraspinatus fossa and superior border may remain superimposed by the clavicle (**Fig. 5.98**). In this situation, little can be done to draw the scapula away from the thoracic cavity, although the exposure can be taken on expiration and a decrease in exposure used that will better demonstrate the parts of the scapula superimposed by the thorax. An AP scapular body projection can be obtained in a trauma situation by using the AP oblique (Grashey) shoulder projection, as discussed earlier in this chapter. In this projection, the patient is rotated toward the affected shoulder, bringing the scapula body AP. If the arm is not adequately abducted and the scapula does not move from beneath the thorax, the CR should be centered 0.5 inch (1 cm) more medial.

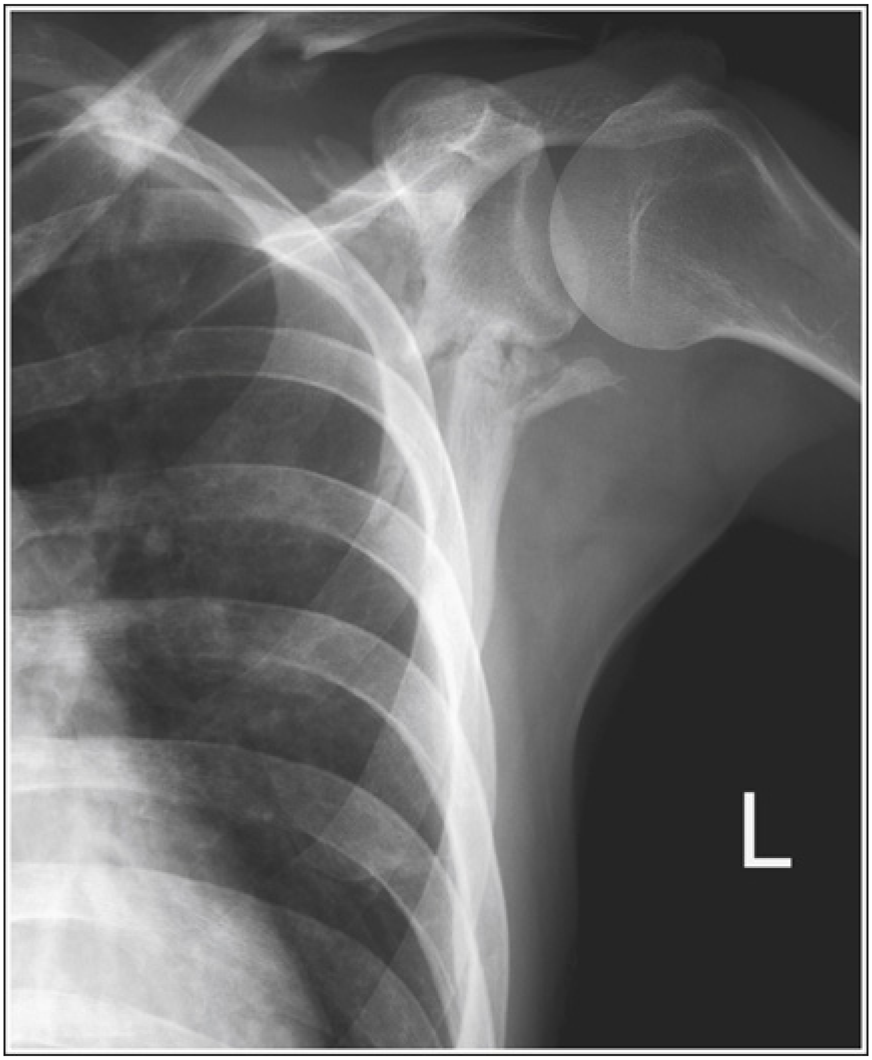


FIGURE 5.98 AP scapular projection demonstrating a scapular fracture.

AP Scapular Analysis Practice

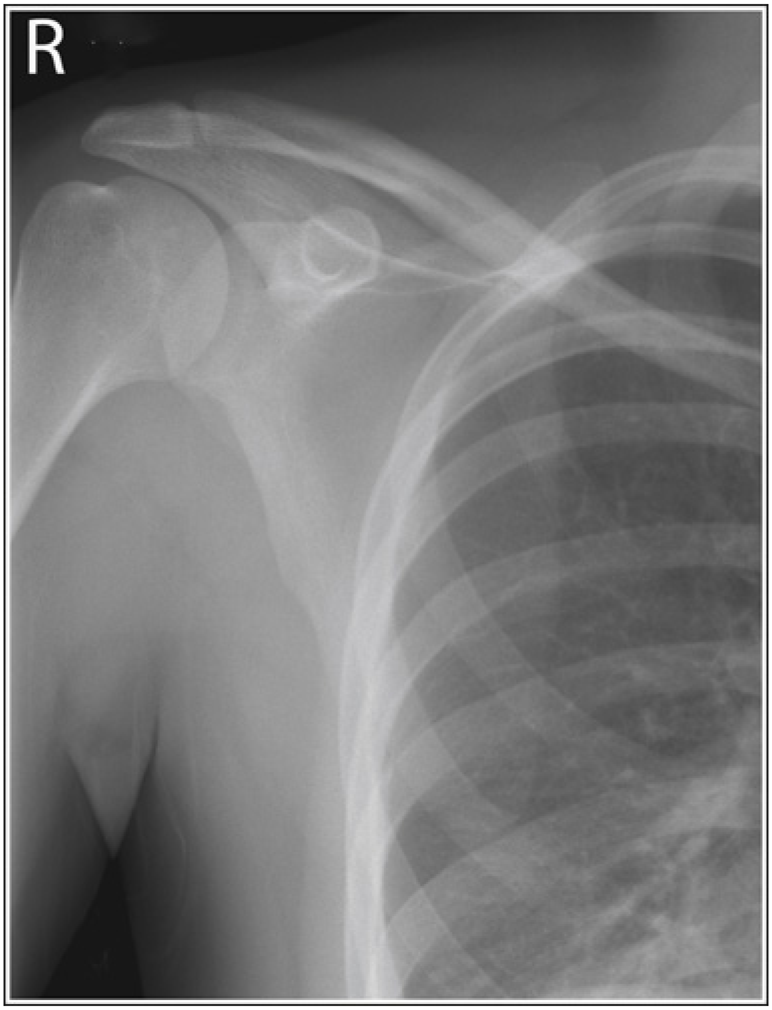


IMAGE 5.20

Analysis

The inferolateral border of the scapula is superimposed by the thoracic cavity, and the superior angle is superimposed by the clavicle. The humerus was not adequately abducted.

Correction

Abduct the humerus to a 90-degree angle with the torso.

Scapula: Lateral Projection (Lateromedial or Mediolateral)

See **Table 5.12** and **Figs. 5.99–5.102**.

TABLE 5.12

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor; *PA*, posteroanterior.

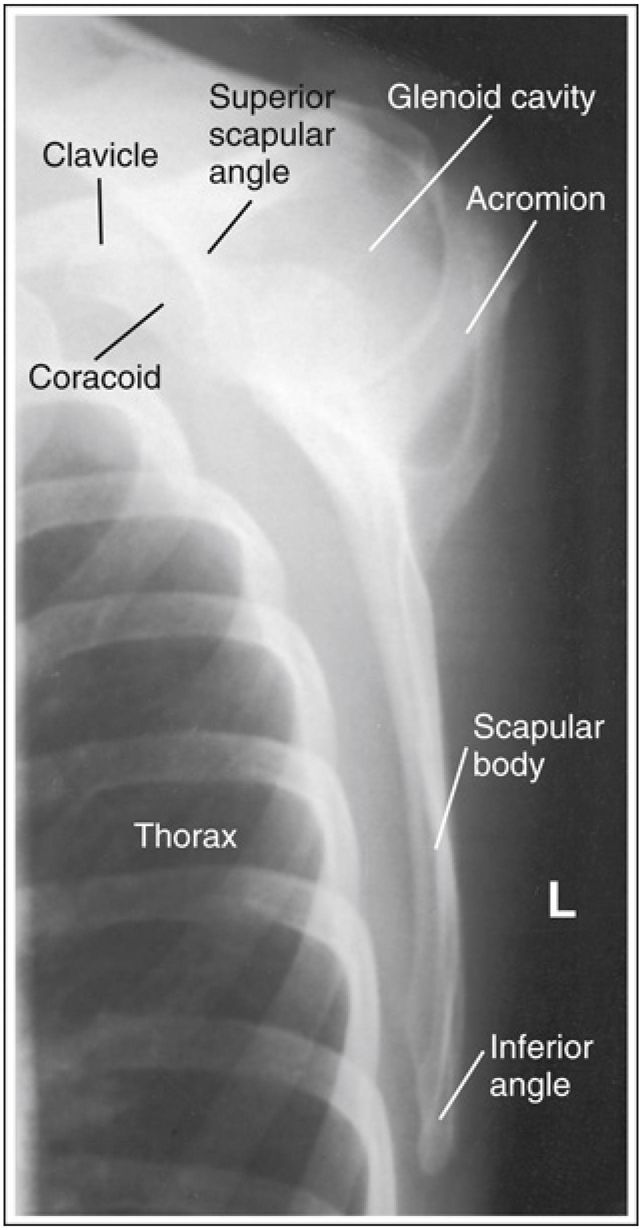


FIGURE 5.99 Lateral scapular projection taken with the arm abducted to 90 degrees and the long axis of the scapular body aligned parallel with the IR.

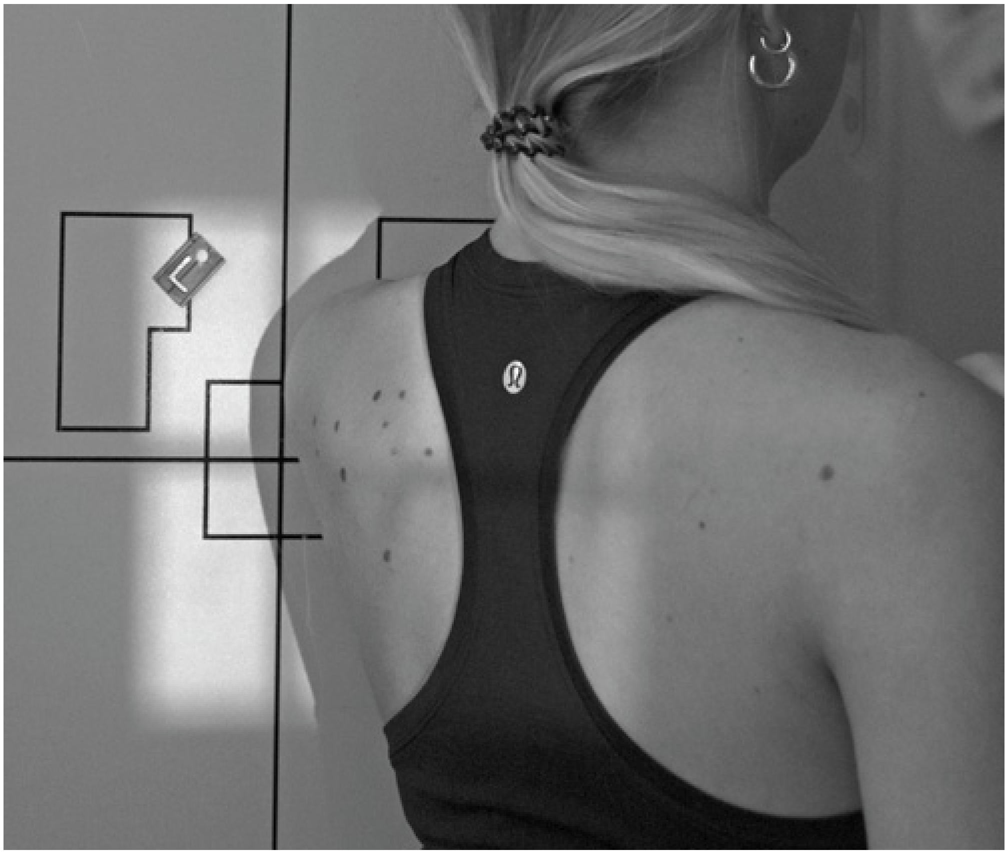


FIGURE 5.100 Proper standing lateral scapular positioning.

FIGURE 5.101 Lateral scapular positioning with the arm abducted to 90 degrees.

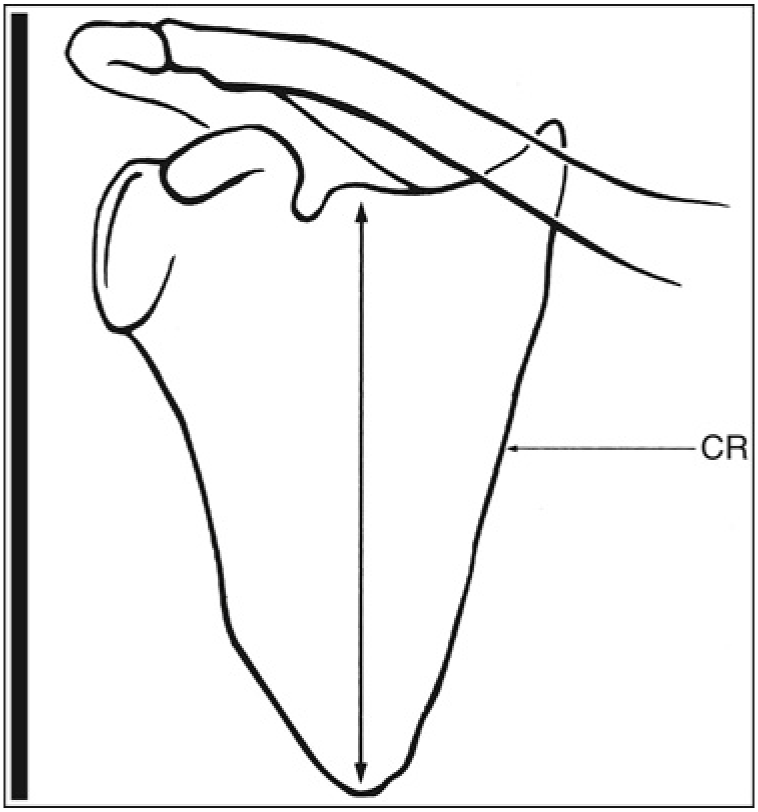


FIGURE 5.102 Long axis of scapular body parallel with the IR.

Humerus at 90-Degree Angle With Torso

Eighty percent of scapular fractures involve the body or neck of the scapula. The neck of the scapula is best visualized on the AP scapula projection, because it is demonstrated on end in the lateral projection. If a fracture of the scapular body is present or suspected, the lateral projection is taken to demonstrate the anterior and the posterior alignment of the fracture. To demonstrate the scapular body best, position its long axis parallel with the long axis of the IR by abducting the humerus to a 90-degree angle with the body (**Figs. 5.101** and **5.102**). This positioning causes the scapula to glide anteriorly around the thoracic cavity and tilts the glenoid fossa slightly upward, placing the long axis of the scapular body parallel with the IR (see

Fig. 5.99). The humerus is also drawn away from the superior scapular body, allowing it to be visualized without humeral superimposition.

Nonabducted Humerus

If the humerus is not abducted but rests on the chest or is less than 90 degrees with the torso, with the patient still grasping the opposite shoulder, the vertebral border of the scapula is positioned closer to parallel with the IR (**Figs. 5.103** and **5.104**). This arm positioning produces a projection similar to that obtained for the PA oblique (scapular Y) projection, where the superior scapular body is superimposed over the glenoid cavity and the proximal humerus, the coracoid and acromion processes are visible in profile, and the glenoid cavity is demonstrated on end (**Fig. 5.105**).

FIGURE 5.103 Lateral scapular positioning with arm resting against thorax.

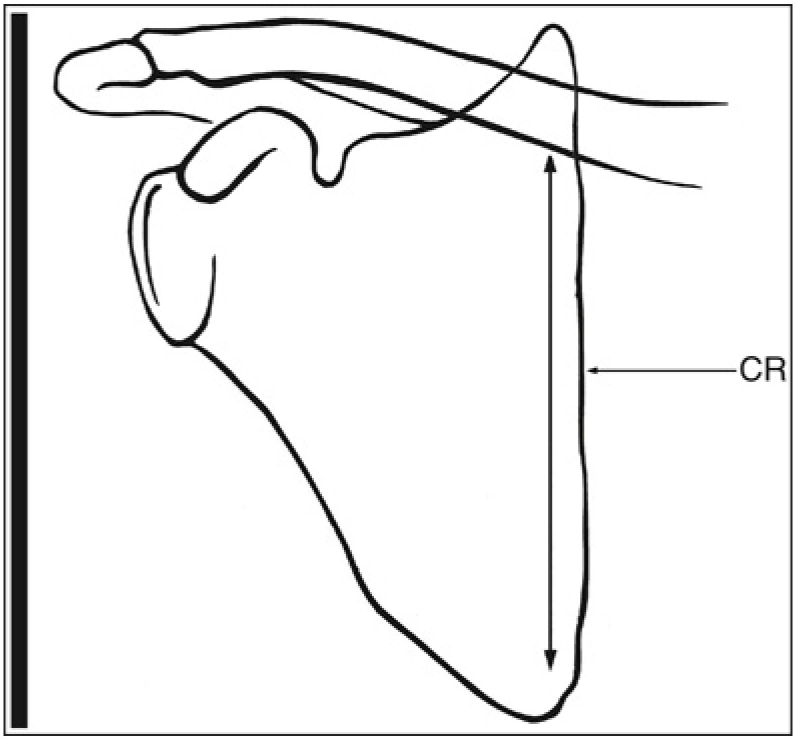


FIGURE 5.104 Vertebral border of scapula parallel with the IR.

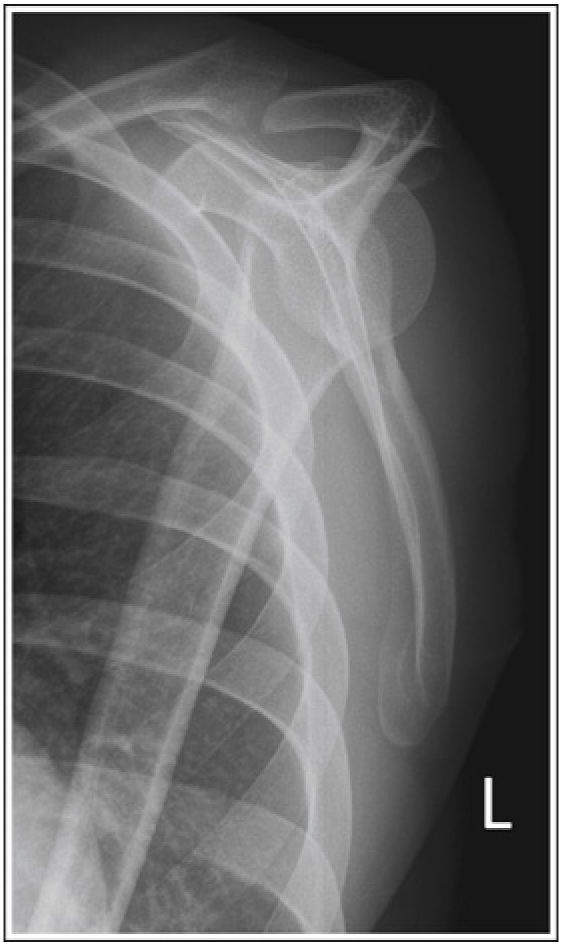


FIGURE 5.105 Lateral scapular projection taken with the arm resting on the chest and the vertebral border of the scapula positioned parallel with the IR.

Humerus Abducted More Than 90 Degrees

If humeral abduction is increased above 90 degrees for a lateral scapula projection, the lateral border of the scapula is placed more parallel with the IR (**Figs. 5.106** and **5.107**). This positioning distorts the superior scapular body and demonstrates the superior scapular angle and scapular spine inferior to the coracoid and acromion processes, respectively, on the resulting projection (**Fig. 5.108**).

FIGURE 5.106 Lateral scapular positioning with arm elevated above 90 degrees.

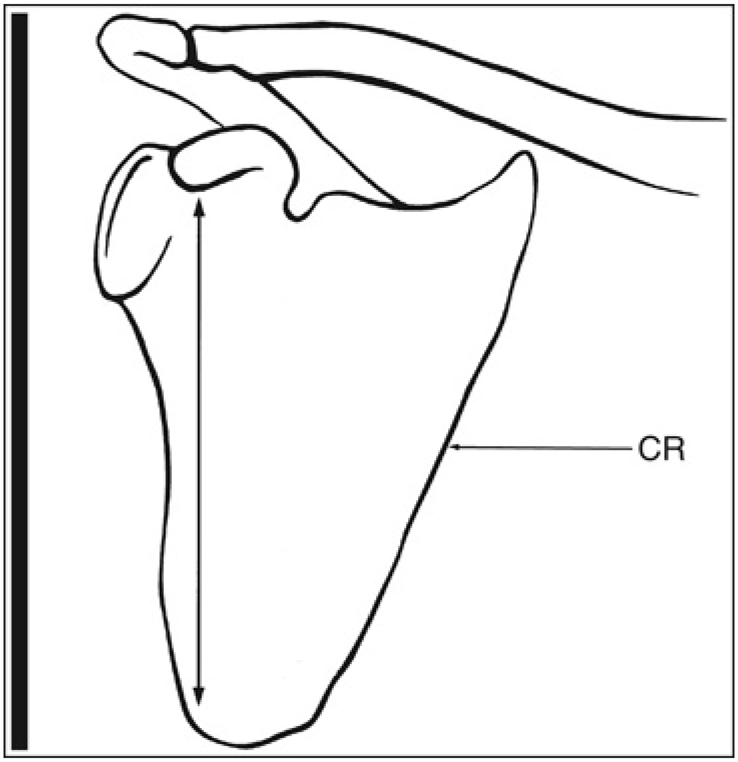


FIGURE 5.107 Lateral border of scapula parallel with the IR.

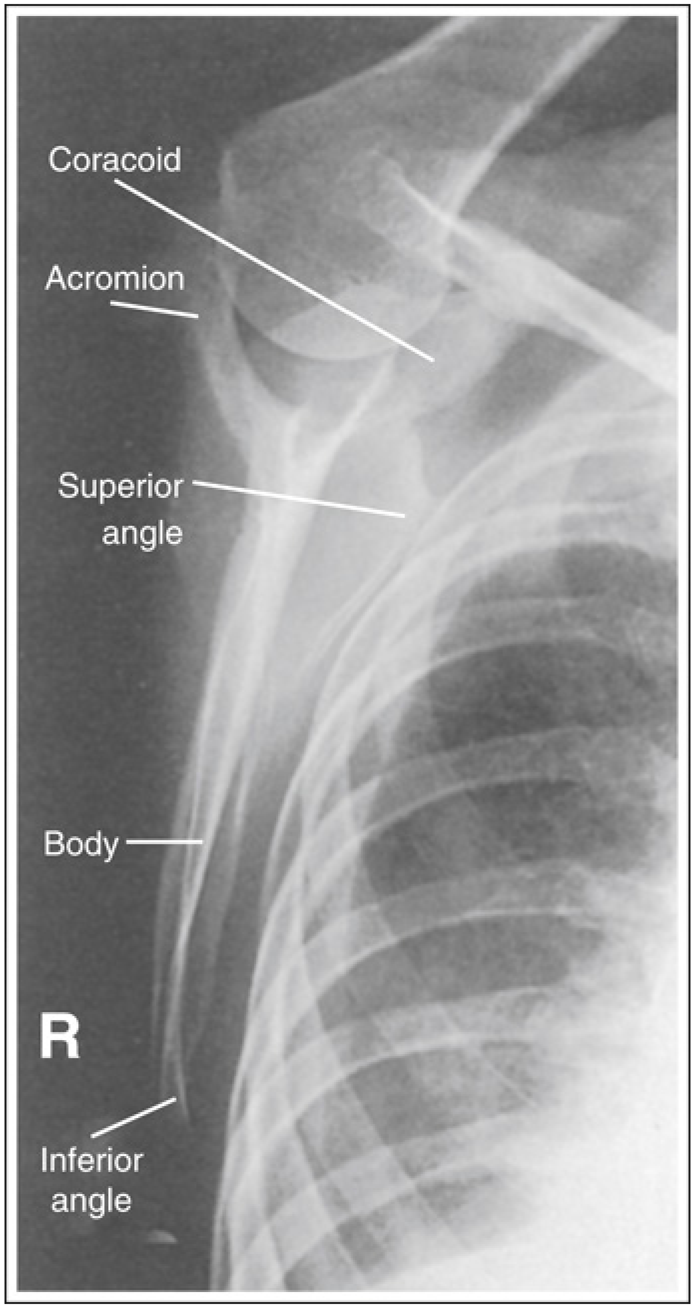


FIGURE 5.108 Lateral scapular projection taken with the arm elevated above 90 degrees and the lateral borders of scapula positioned parallel with the IR.

Midcoronal Plane Positioning and Scapular Obliquity

The degree of body obliquity required to superimpose the scapular borders for a lateral scapula projection depends on the degree of humeral abduction. As the humerus is abducted, the inferior angle of the scapula glides around the thoracic cage, moving the scapula more anteriorly. The more the humerus is abducted, the more the scapula glides around the thorax and the less body obliquity that is needed to superimpose the vertebral and lateral scapular borders. One method of determining the degree of body rotation needed is to use the palpable lateral and vertebral scapular borders. Because the superior portions of the lateral and vertebral borders are heavily covered with muscles, it is best to palpate them just superior to the inferior scapular angle. Adjusting the degree of arm abduction while palpating will move the location of the inferior angle and help in locating the inferior angle and scapular borders. Once the scapular borders are located, position the arm in the desired degree of abduction and rotate the body until the vertebral border of the scapula is superimposed over the lateral border and the inferior scapular angle is positioned in profile.

Insufficient Torso and Scapular Rotation

If the vertebral scapular border is superimposed by the thorax or is demonstrated closer to the thorax than the lateral scapular border on a lateral scapula projection, the torso and scapular rotation was insufficient (**Fig. 5.109**).

FIGURE 5.109 Lateral scapular projection taken with insufficient scapular obliquity.

Excessive Torso and Scapular Rotation

If the lateral scapular border is superimposed by the thorax or is positioned closer to the thorax than the vertebral scapular border on a lateral scapula projection, the torso and scapular rotation was excessive (**Fig. 5.110**).

FIGURE 5.110 Lateral scapular projection taken with excessive scapular obliquity.

Lateral Scapular Analysis Practice

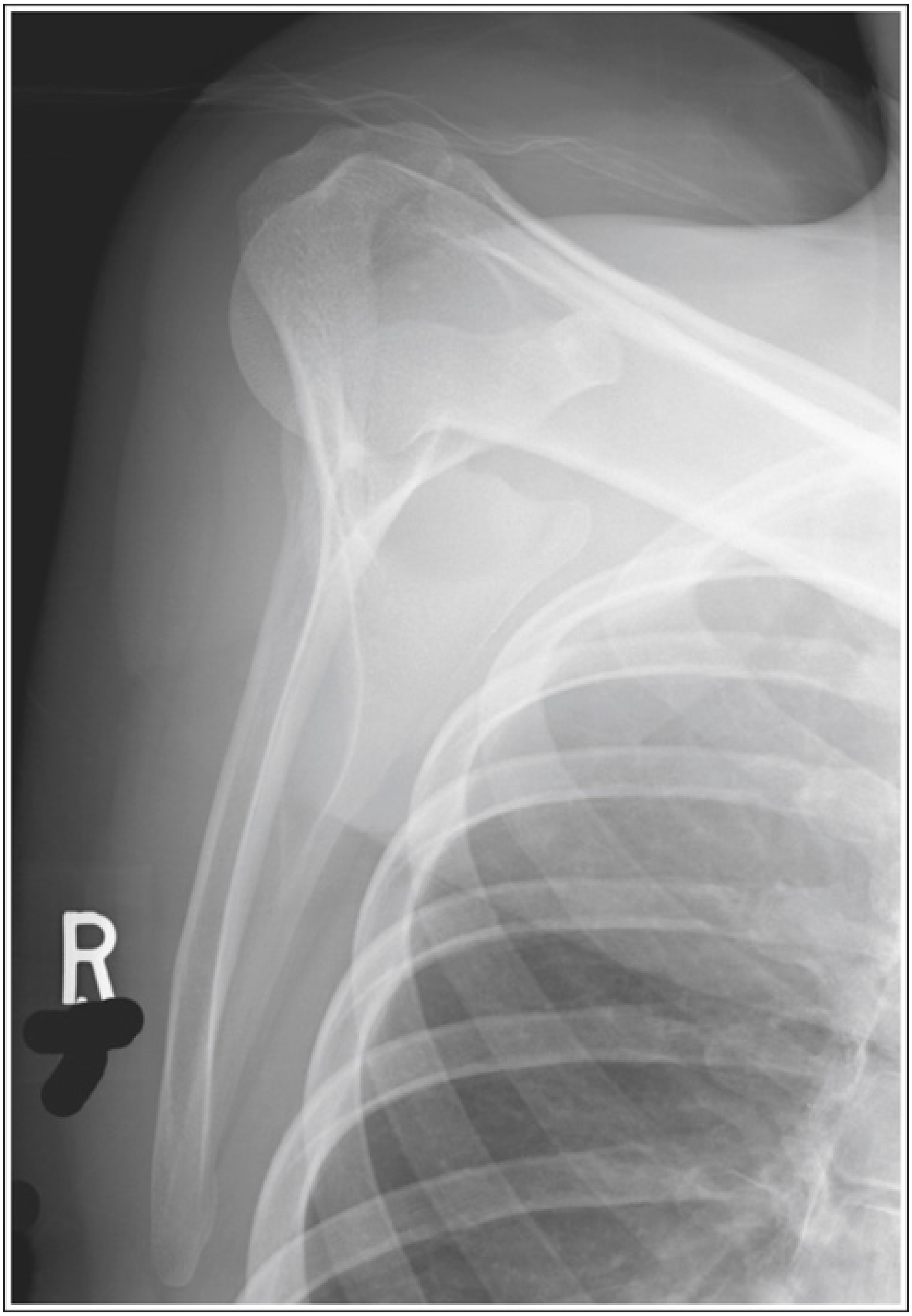


IMAGE 5.21

Analysis

The lateral and vertebral borders of the scapula are demonstrated without superimposition. The vertebral border is seen closer to the ribs. The torso and shoulder were insufficiently rotated. The superior scapular angle is inferior to the coracoid. The humerus was abducted more than 90 degrees.

Correction

Increase the degree of torso and shoulder obliquity and adduct the humerus to a 90-degree angle with the torso.

Chapter 6: Image Analysis of the Lower Extremity

OBJECTIVES

AFTER COMPLETION OF THIS CHAPTER, YOU SHOULD BE ABLE TO DO THE FOLLOWING:

- IDENTIFY THE REQUIRED ANATOMY ON LOWER EXTREMITY PROJECTIONS.

- DESCRIBE HOW TO POSITION THE PATIENT, IMAGE RECEPTOR (IR), AND CENTRAL RAY (CR) FOR PROPER LOWER EXTREMITY PROJECTIONS.
- LIST THE IMAGE ANALYSIS REQUIREMENTS FOR ACCURATE POSITIONING FOR LOWER EXTREMITY PROJECTIONS.
- STATE HOW TO REPOSITION THE PATIENT PROPERLY WHEN LOWER EXTREMITY PROJECTIONS WITH POOR POSITIONING ARE PRODUCED.
- DISCUSS HOW TO DETERMINE THE AMOUNT OF PATIENT OR CR ADJUSTMENT REQUIRED TO IMPROVE LOWER EXTREMITY PROJECTIONS WITH POOR POSITIONING.
- STATE THE KILOVOLTAGE ROUTINELY USED FOR LOWER EXTREMITY PROJECTIONS, AND DESCRIBE WHICH ANATOMIC STRUCTURES ARE VISIBLE WHEN THE CORRECT TECHNIQUE FACTORS ARE USED.
- DESCRIBE WHICH ASPECTS OF A TOE'S PHALANGES ARE CONCAVE AND WHICH ARE CONVEX.
- STATE HOW THE CR ANGULATION IS ADJUSTED FOR AN AP AXIAL TOE PROJECTION WHEN THE PATIENT IS UNABLE TO EXTEND THE TOE FULLY.
- DISCUSS HOW THE DEGREE OF CR ANGULATION IS ADJUSTED FOR AN AP AXIAL FOOT PROJECTION AND HOW THE DEGREE OF OBLIQUITY IS ADJUSTED FOR AN AP OBLIQUE FOOT PROJECTION IN PATIENTS WITH HIGH AND LOW MEDIAL LONGITUDINAL ARCHES.

- STATE HOW ONE CAN DETERMINE FROM TWO DIFFERENT AP OBLIQUE FOOT PROJECTIONS WHICH FOOT HAS THE HIGHER LONGITUDINAL ARCH.
- STATE HOW THE HEIGHT OF A MEDIAL LONGITUDINAL ARCH CAN BE EVALUATED ON A LATERAL FOOT PROJECTION.
- STATE WHICH ANATOMIC STRUCTURES ARE REFERRED TO AS THE *TALAR DOMES* ON A LATERAL FOOT, CALCANEAL, OR ANKLE PROJECTION.
- DESCRIBE HOW THE CR ANGULATION IS ADJUSTED WHEN A PATIENT IS UNABLE TO DORSIFLEX THE FOOT FOR AN AXIAL CALCANEAL PROJECTION.
- STATE HOW THE MEDIAL AND LATERAL TALAR DOMES CAN BE IDENTIFIED ON A LATERAL FOOT, CALCANEAL, OR ANKLE PROJECTION WITH POOR POSITIONING.
- EXPLAIN WHY THE IR MUST EXTEND BEYOND THE KNEE AND ANKLE JOINTS WHEN THE LOWER LEG IS IMAGED.
- EXPLAIN HOW THE PATIENT IS POSITIONED IF ONLY ONE OF THE JOINTS CAN BE IN THE TRUE POSITION FOR AP OR LATERAL LOWER LEG PROJECTIONS.
- EXPLAIN HOW THE CR ANGULATION USED FOR AP AND OBLIQUE KNEE PROJECTIONS IS DETERMINED BY THE THICKNESS OF THE UPPER THIGH AND BUTTOCKS, AND DISCUSS WHY THIS ADJUSTMENT IS REQUIRED.

- DESCRIBE A VALGUS AND A VARUS KNEE DEFORMITY.
- STATE HOW TO DETERMINE WHAT CR ANGULATION TO USE FOR AN AP KNEE PROJECTION IN A PATIENT WHO CANNOT FULLY EXTEND THE KNEE.
- DESCRIBE A PATELLA SUBLUXATION, AND STATE HOW IT IS DEMONSTRATED ON AN AP KNEE PROJECTION.
- STATE WHICH ANATOMIC STRUCTURES ARE PLACED IN PROFILE ON MEDIAL AND LATERAL OBLIQUE KNEE PROJECTIONS WITH ACCURATE POSITIONING.
- LIST THE SOFT TISSUE STRUCTURES OF INTEREST FOUND ON LOWER LEG PROJECTIONS. STATE WHERE THEY ARE LOCATED AND WHY THEIR VISUALIZATION IS IMPORTANT.
- STATE HOW THE KNEE IS POSITIONED FOR A LATERAL KNEE PROJECTION IF A PATELLA FRACTURE IS SUSPECTED.
- STATE THE RELATIONSHIP OF THE MEDIAL AND LATERAL FEMORAL CONDYLES, AND DESCRIBE THE DEGREE OF FEMORAL INCLINATION DEMONSTRATED IN A PATIENT IN AN ERECT AND LATERAL RECUMBENT POSITION.
- STATE THE FEMORAL LENGTH AND PELVIC WIDTH THAT DEMONSTRATE THE LEAST AMOUNT OF FEMORAL INCLINATION.
- DESCRIBE TWO METHODS THAT CAN BE USED TO DISTINGUISH THE MEDIAL AND LATERAL FEMORAL CONDYLES FROM EACH OTHER ON A

LATERAL KNEE PROJECTION WITH POOR POSITIONING.

- STATE TWO WAYS THAT THE PATIENT AND CR ANGLE CAN BE ALIGNED TO ACCOMPLISH SUPERIMPOSED FEMORAL CONDYLES FOR A LATERAL KNEE PROJECTION.
- DESCRIBE HOW PATELLAR SUBLUXATION IS DEMONSTRATED ON A TANGENTIAL (AXIAL) KNEE PROJECTION.
- STATE THE IMPORTANCE OF SECURING THE LEGS AND INSTRUCTING THE PATIENT TO RELAX THE QUADRICEPS FEMORIS MUSCLES FOR A TANGENTIAL (AXIAL) KNEE PROJECTION.
- EXPLAIN HOW THE POSITIONING SETUP FOR A TANGENTIAL (AXIAL) PROJECTION IS ADJUSTED FOR A PATIENT WITH LARGE POSTERIOR CALVES.
- STATE WHY A 72-INCH (183-CM) SOURCE–IMAGE RECEPTOR DISTANCE (SID) IS REQUIRED FOR A TANGENTIAL (AXIAL) KNEE PROJECTION.
- DISCUSS THE IMPORTANCE OF INCLUDING THE FEMORAL SOFT TISSUE ON ALL FEMORAL PROJECTIONS.
- EXPLAIN HOW A DISTAL AND PROXIMAL AP AND LATERAL FEMORAL PROJECTION IS OBTAINED IN A PATIENT WITH A SUSPECTED FRACTURE.
- STATE WHY THE LEG IS NEVER ROTATED WHEN A FEMORAL FRACTURE IS SUSPECTED.

KEY TERMS **ADDUCTOR TUBERCLE BASE OF SUPPORT (BOS) CENTER OF GRAVITY (COG) DORSAL DORSIFLEXION DORSOPLANTAR INTERMALLEOLAR**

LINE LATERAL MORTISE PLANTAR PLANTAR-FLEXION SUBLUXATION TALAR DOMES TARSI SINUS VALGUS DEFORMITY VARUS DEFORMITY

Image Analysis Guidelines

Technical Data

See **Table 6.1** and **Box 6.1**.

Weight-Bearing Projections

Many of the projections obtained on the lower extremity give a non–weight-bearing and weight-bearing option. The weight-bearing option should only be used when the patient is stable in the standing position and can put weight on the foot of the affected leg with the knee extended.

Toe: AP Axial Projection

See **Table 6.2** and Figs. **6.1**–**6.4**.

Toe and Foot Rotation

Compare the toe projections in **Fig. 6.5**. Note that in an anteroposterior (AP) projection, concavity of the midshaft of the proximal phalanx is equal on both sides, and in the lateral projection the posterior (plantar) surface of the proximal phalanx demonstrates more concavity than the anterior (dorsal) surface. Also note that as the toe is rotated for an AP oblique projection, the amount of concavity increases on the side toward which the posterior surface is rotated, whereas the side toward which the anterior surface is rotated demonstrates less concavity. The same observations can be made about the soft tissue that surrounds the phalanges. Equal soft tissue width is demonstrated on each side of the AP toe, there is more soft tissue thickness on the posterior surface than the anterior surface on a lateral toe, and the side demonstrating the greatest soft tissue width on an AP oblique toe is the side toward which the posterior surface is rotated.

TABLE 6.1

[a] Use grid if part thickness measures 4 inches (10 cm) or more and adjust mAs per grid ratio requirement.

Box 6.1 Lower Extremity Guidelines

VOI, Values of interest.

- The facility's identification requirements are visible.

- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomic structures are sharply defined.
- Contrast resolution is adequate to demonstrate the surrounding soft tissue, bony trabecular patterns, and cortical outlines.
- No quantum mottle or saturation is present.
- Scattered radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

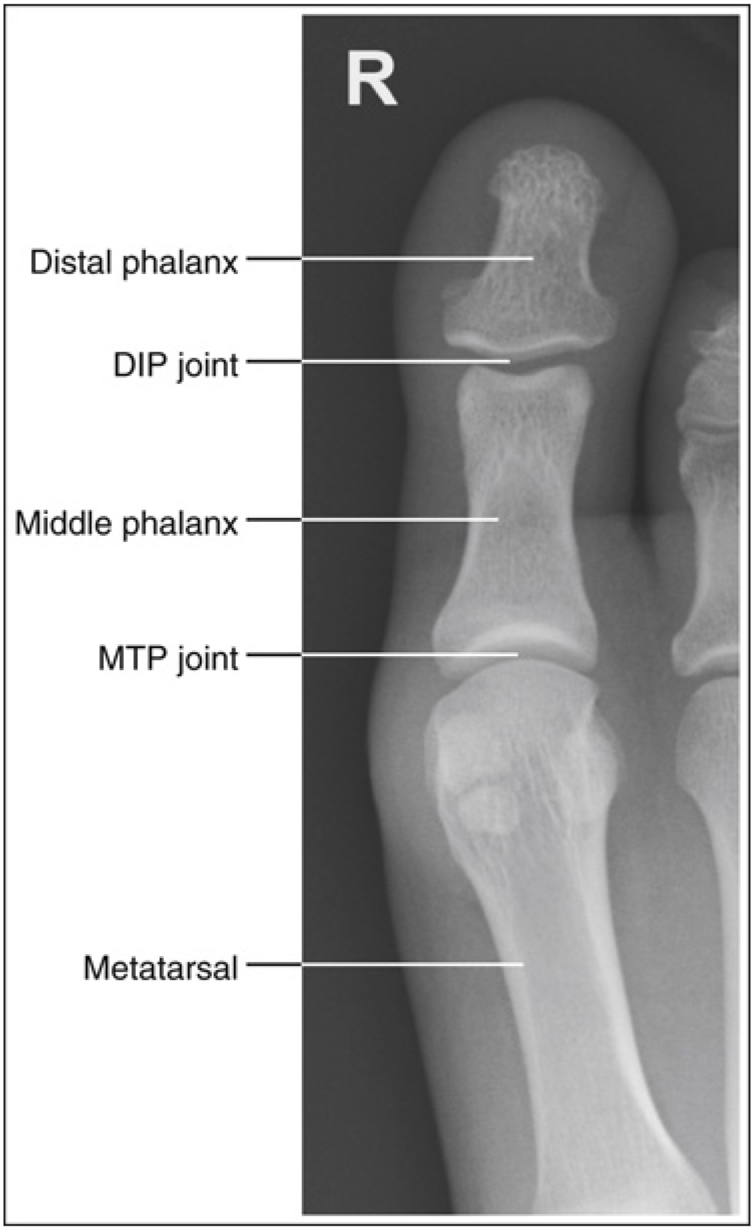


FIGURE 6.1 First AP axial toe projection with accurate positioning. *DIP*, Distal interphalangeal; *MTP*, metatarsophalangeal.

FIGURE 6.2 Second AP axial toe projection with accurate positioning.

FIGURE 6.3 AP axial projection of the toes with accurate positioning.

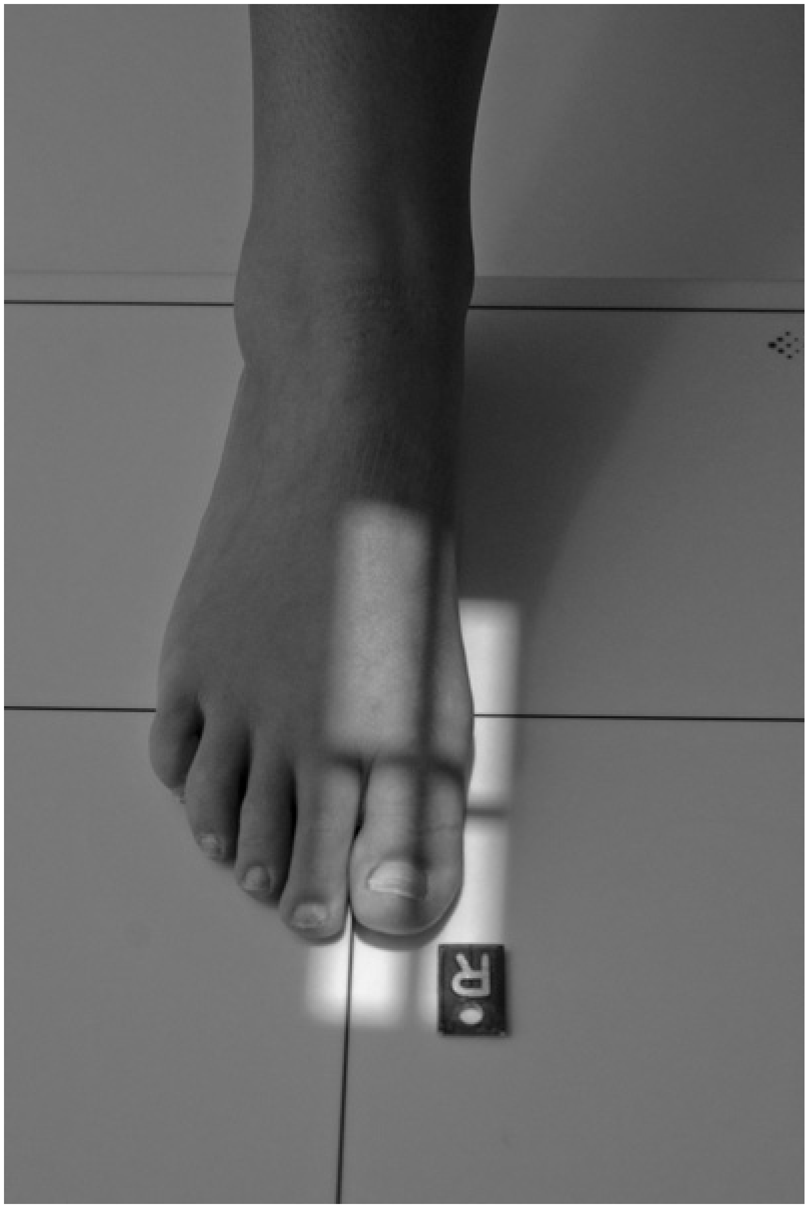


FIGURE 6.4 Proper patient positioning for AP axial toe projection.

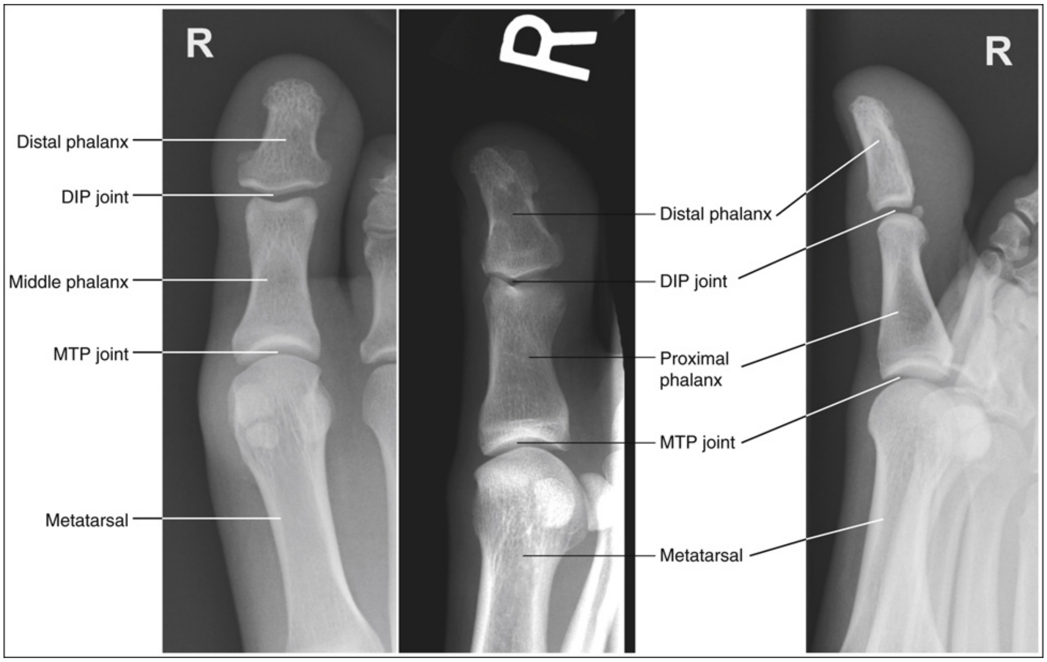


FIGURE 6.5 AP, AP oblique, and lateral toe projections for demonstrating soft tissue and phalanx concavity comparison.

FIGURE 6.6 AP axial toe projection taken with the toe rotated laterally.

TABLE 6.2

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MT*, metatarsal; *MTP*, metatarsophalangeal; *PIP*, proximal interphalangeal joint.

Lateral Toe Rotation

When the toe and foot are rotated laterally for an AP toe projection, the phalangeal soft tissue width and midshaft concavity are greater on the

medial side of the toe, which is the side positioned away from the image receptor (IR; **Fig. 6.6**).

Medial Toe Rotation

When the toe and foot are rotated medially, the phalangeal soft tissue width and midshaft concavity are greater on the lateral side of the toe, which is the side positioned away from the IR (**Fig. 6.7**).

Open Joint Spaces and Unforeshortened Phalanges

The angulation placed on the central ray (CR) is required to align the CR closer to parallel with the joint spaces and perpendicular to the phalanges, preventing closed joint spaces and foreshortened phalanges (**Fig. 6.8**).

Positioning for Nonextendable Toes

For patients who have flexed toes that will not extend and would require greater than a 15-degree CR angulation for the CR to be aligned accurately with the joint space or phalange, the toes and forefoot may be elevated on a radiolucent sponge to bring the phalanges more parallel with the IR. If this is not done, the angle between the CR and IR will be too acute, causing elongation and projecting of the toe(s) into the foot. Unfortunately this elevation will cause magnification and needs to be kept to a minimum.

FIGURE 6.7 AP axial toe projection taken with the toe rotated medially.

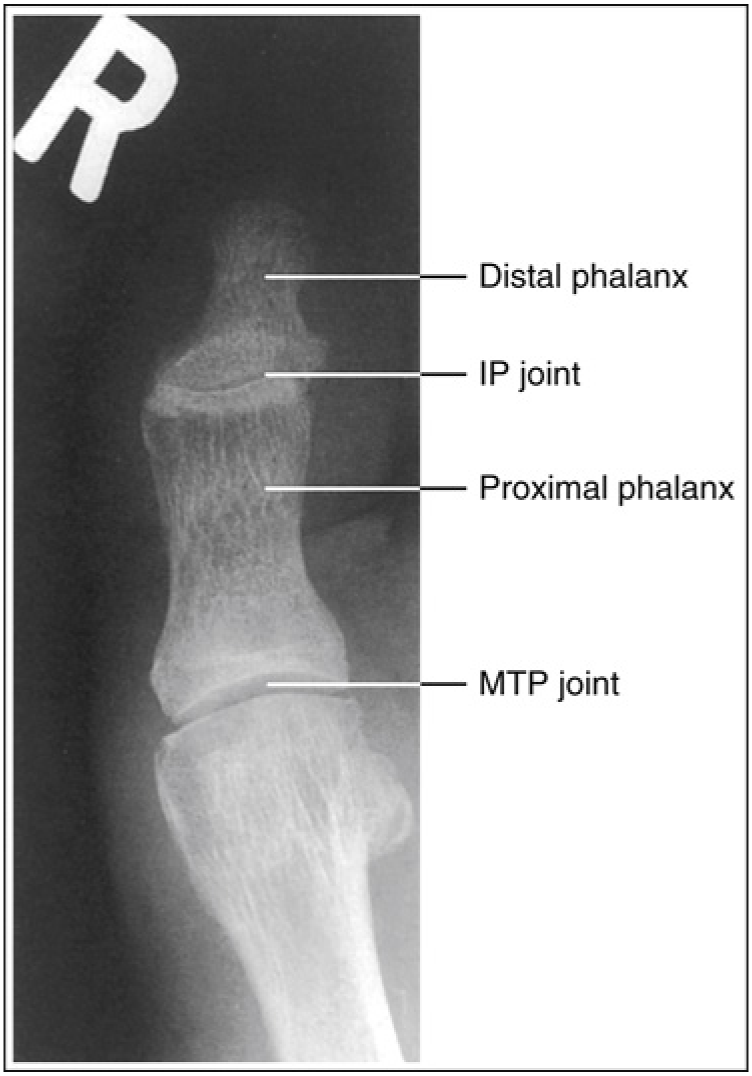


FIGURE 6.8 AP axial toe projection taken without the CR aligned parallel with the IP and MTP joint spaces.

AP Axial Toe Analysis Practice

IMAGE 6.1

Analysis

The phalanges demonstrate greater soft tissue width and midshaft concavity on the medial surface. The toe was laterally rotated.

Correction

Medially rotate the foot and toe until they are flat against the IR.

IMAGE 6.2

Analysis

The phalanges demonstrate greater soft tissue width and midshaft concavity on the lateral surface. The toe and foot were medially rotated.

Correction

Laterally rotate the foot until the posterior toe of interest is flat against the IR.

IMAGE 6.3

Analysis

The interphalangeal (IP) joint spaces are closed, and the distal phalanx is foreshortened. The toe was flexed, and the CR was not aligned parallel with the joint spaces or perpendicular to the distal phalanx. There is soft tissue superimposition with the second toe.

Correction

If the patient's condition allows, extend the toe, placing it flat against the IR. If the patient is unable to extend the toe, increase the degree of CR angulation, or elevate the toe and forefoot on a radiolucent sponge until the joint space of interest is perpendicular or the phalanx of interest is parallel with the IR. Separate the first and second toes so their soft tissue does not superimpose.

Toe: AP Oblique Projection

See **Table 6.3** and Figs. **6.9–6.11**.

Insufficient Toe Obliquity

When the midshaft concavity of the proximal phalanx and soft tissue width are closer to equal on both sides of the digit on an AP oblique toe projection, the toe was not adequately rotated (**Fig. 6.12**).

Excessive Toe Obliquity

When more than twice the width of soft tissue is present on one side of the digit than on the other and when the posterior aspect of the proximal phalanx's midshaft demonstrates more concavity than the anterior aspect, the toe was rotated more than 45 degrees for the AP oblique toe projection (**Fig. 6.13**).

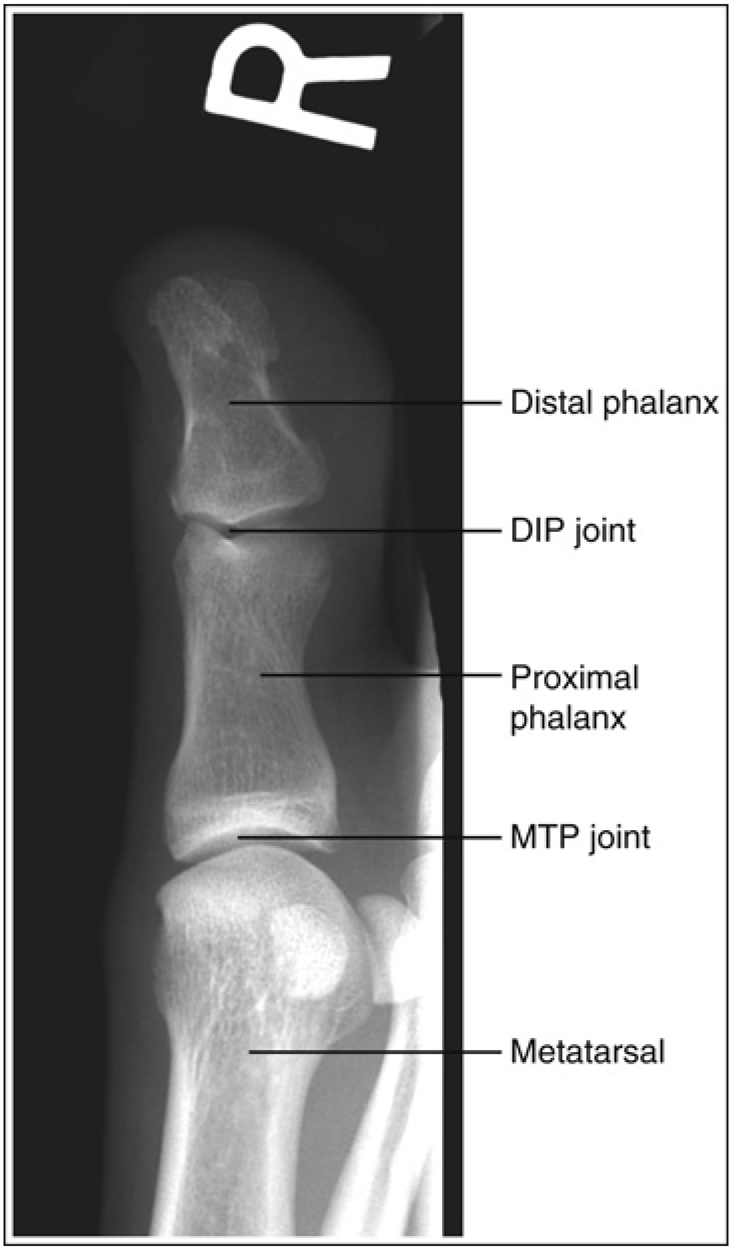


FIGURE 6.9 AP oblique toe projection with accurate positioning.

FIGURE 6.10 AP oblique projections of the toes with accurate positioning.

FIGURE 6.11 Proper patient positioning for AP oblique toe projection.

FIGURE 6.12 AP oblique toe projection taken without adequate toe obliquity.

TABLE 6.3

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MT*, metatarsal; *MTP*, metatarsophalangeal; *PIP*, proximal interphalangeal joint.

FIGURE 6.13 AP oblique toe projection taken with excessive toe obliquity.

FIGURE 6.14 AP oblique toe projection taken without the CR aligned parallel with the IP and MTP joint spaces.

Open Joint Spaces and Unforeshortened Phalanges

If the toe is not fully extended and/or the CR is not centered to the metatarsophalangeal (MTP) joint, the resulting projection demonstrates closed joint spaces and foreshortened phalanges (**Fig. 6.14**).

FIGURE 6.15 AP oblique toe projection taken without a small separation between the toes.

Bony and Soft Tissue Overlap

If the toes' soft tissue is allowed to overlap when positioned, they will overlap each other on the projection, obscuring the soft tissue detail (**Fig. 6.15**).

AP Oblique Toe Analysis Practice

IMAGE 6.4

Analysis

The soft tissue width and midshaft concavity on both sides of the phalanges are almost equal. The toe was rotated less than the required 45 degrees.

Correction

Increase the toe and foot obliquity until the affected toe was at a 45-degree angle with the IR.

Toe: Lateral Projection (Mediolateral and Lateromedial)

See **Table 6.4** and Figs. **6.16**–**6.19**.

TABLE 6.4

CR, Central ray; *IP*, interphalangeal; *IR*, image receptor; *MT*, metatarsal; *MTP*, metatarsophalangeal; *PIP*, proximal interphalangeal joint.

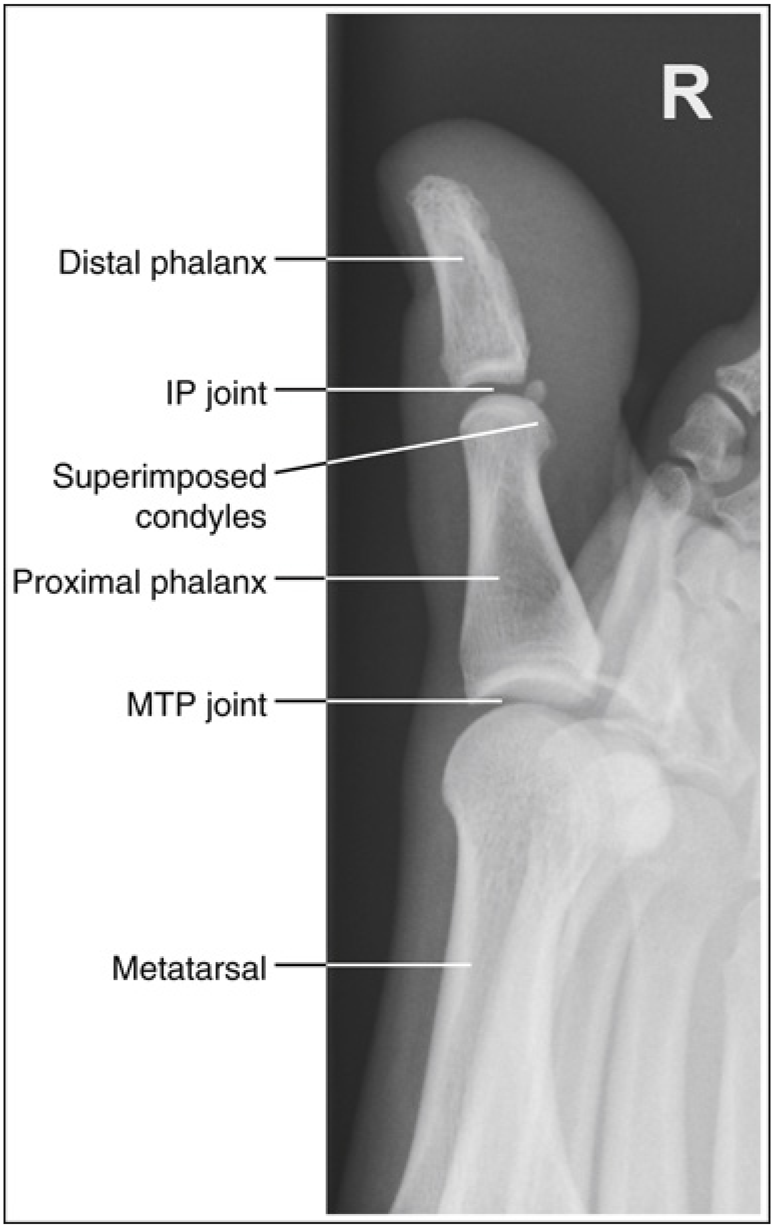


FIGURE 6.16 First lateral toe projection with accurate positioning.

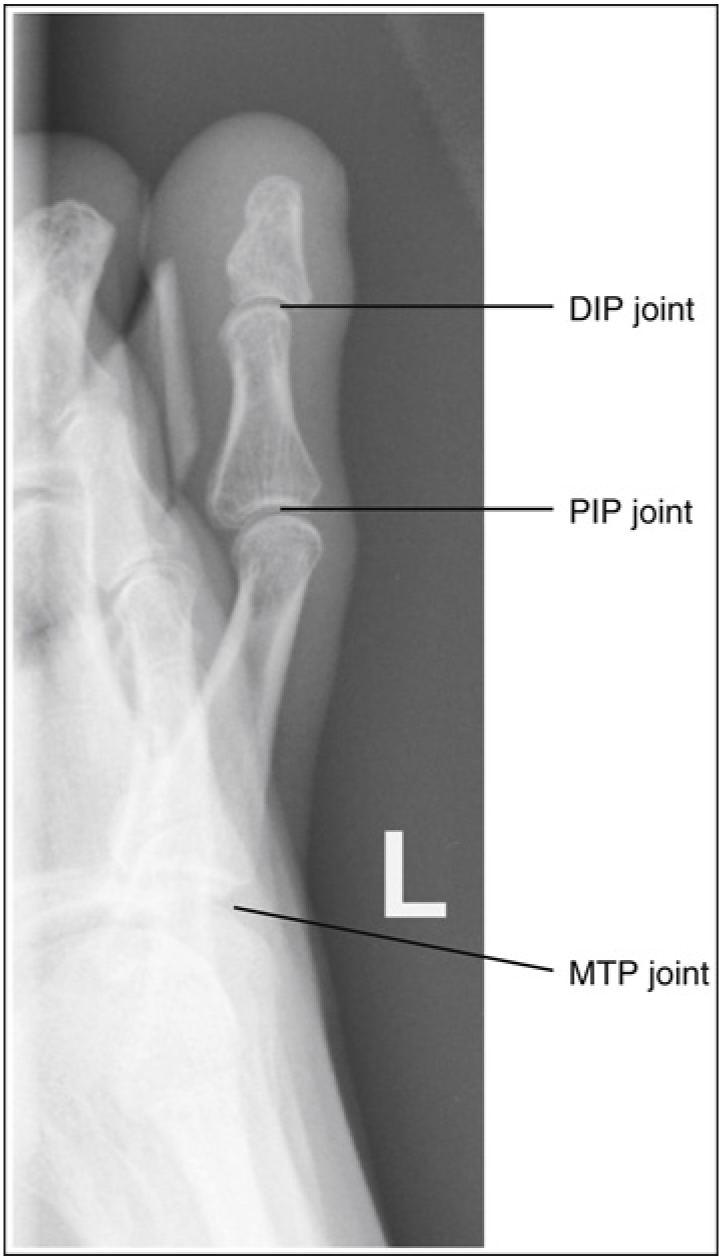


FIGURE 6.17 Second lateral toe projection with accurate positioning.

FIGURE 6.18 Proper patient positioning for lateral projection of the first toe.

FIGURE 6.19 Proper patient positioning for lateral projection of the fifth toe.

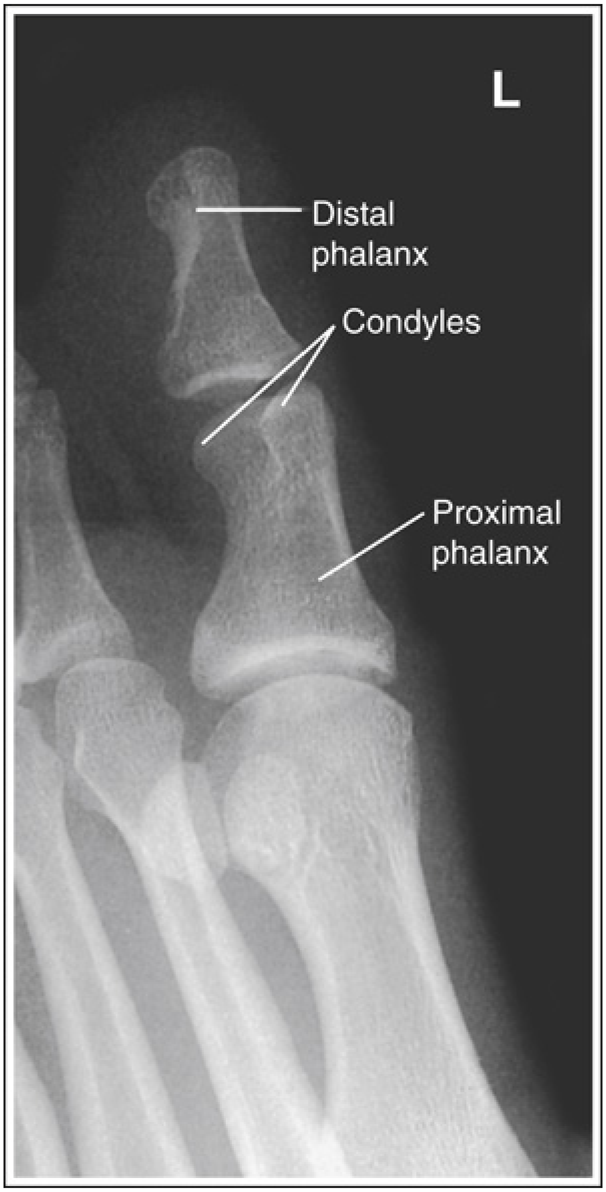


FIGURE 6.20 Lateral toe projection taken without adequate toe obliquity to place the toe in a lateral projection.

FIGURE 6.21 Lateral toe projection taken with excessive toe obliquity.

FIGURE 6.22 Lateral toe projection taken without the unaffected toes being drawn away from the affected first toe.

Insufficient Toe Rotation

If the condyles of the proximal phalanx are not superimposed on lateral toe projection and the metatarsal (MT) heads are shown posterior to the first toe, the toe and foot were not rotated enough for the toe to be placed in a lateral projection (**Fig. 6.20**).

Excessive Toe Rotation

If the condyles of the proximal phalanx are not superimposed and the MT heads are shown superimposing or positioned anterior to the first toe on a lateral toe projection, the toe and foot were rotated more than needed for a lateral toe projection (**Fig. 6.21**).

Bony and Soft Tissue Overlap

Failing to draw the unaffected toes away from the affected toe causes overlap of the bony and soft tissue structures (**Fig. 6.22**).

Lateral Toe Analysis Practice

IMAGE 6.5

Analysis

Soft tissue and bony overlap of digits are present. The adjacent unaffected digits were not drawn away from the affected digit.

Correction

The unaffected toes should be drawn away from the affected toe. It may be necessary to use tape or another immobilization device to help the patient maintain this position.

IMAGE 6.6

Analysis

The condyles of the proximal phalanx are not superimposed, and the MT heads are shown anterior to the first toe. The foot was rotated more than needed to bring the toe into a lateral projection.

Correction

Decrease the degree of foot rotation until the toe is in a lateral projection.

IMAGE 6.7

Analysis

The condyles of the proximal phalanx are not superimposed, and the MT heads are shown posterior to the first toe. The foot was underrotated.

Correction

Increase the degree of foot rotation.

Foot: AP Axial Projection (Dorsoplantar)

See **Table 6.5** and **Figs. 6.23** and **6.24**.

Foot Rotation

The medial side of the foot arches up between the heel and the medial three MTP joints to form a visible longitudinal arch. It is because of this medial arch that the medial plantar surface does not always make contact with the IR for an AP foot projection and why it is important to position the foot so even pressure is placed on the plantar surface, preventing medial and lateral foot rotation. Uneven plantar surface pressure and rotation occurs when the ankle is allowed to invert or evert because the lower leg, ankle, and foot are not aligned for the non–weight-bearing AP foot and when the knees and feet are positioned at a greater or lesser width than hip width apart for the weight-bearing AP foot. Study the projections in **Fig. 6.25** to compare the changes in the relationship among the MTs, the cuneiforms, and the amount of talar and calcaneal superimposition that occurs when the AP foot projection is obtained with medial or lateral rotation.

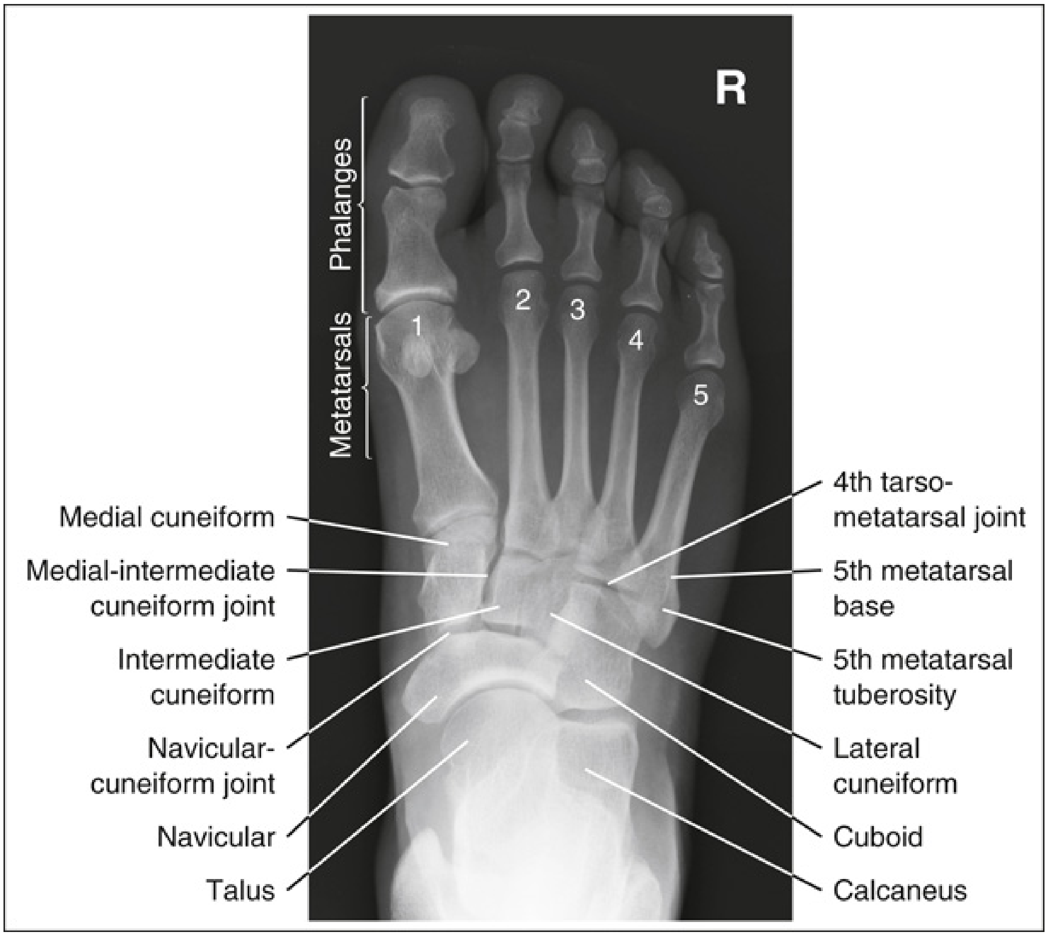


FIGURE 6.23 AP axial foot projection with accurate positioning.

TABLE 6.5

AP, Anteroposterior; *BOS,* base of support; *COG,* center of gravity; *CR,* central ray; *IR,* image receptor; *MT,* metatarsal; *TMT,* tarsometatarsal.

Lateral Rotation

When the foot is laterally rotated, the MT bases demonstrate increased superimposition, the medial and intermediate cuneiform joint is closed, and the talus moves over the calcaneus, resulting in more than one-third of the

talus superimposing the calcaneus (<0.75 inch [2 cm] of calcaneal demonstration without talar superimposition).

Medial Rotation

When the foot is medially rotated, the MT bases demonstrate decreased superimposition, the medial and intermediate cuneiform joint is closed, and the talus moves away from the calcaneus, resulting in less than one-third of the talus superimposing the calcaneus (>0.75 inch [2 cm] calcaneal visualization without talar superimposition).

FIGURE 6.24 Proper patient positioning for AP axial foot projection.

Weight-Bearing: Body Mechanics

Weight-bearing projections are obtained to demonstrate how the body part(s) reacts when the patient's body weight is acted upon it. The center of

gravity (COG) is a point in the center of the pelvis that is a little above the hip joints and anterior to the second sacral vertebrae and is where the weight is equally distributed on all sides (**Fig. 6.26**). The anteroposterior location of the COG is determined by the line of gravity (LOG), which is an imaginary plane that runs the length of the body, through the COG, and down to the ground, dividing the body into two equal halves. For standing projections when the COG is positioned over the center of the base of support (BOS), which is the point directly between the feet, the patient is in a state of equilibrium, with equal pressure applied to both feet. The BOS's size increases and center point moves as the feet are positioned farther apart from each other by widening the space between them or stepping one foot in front of the other as demonstrated in **Fig. 6.27**. A larger BOS provides more stability. When the COG moves away from the center of the BOS, the weight is not equally distributed across both feet, and when the COG moves outside the BOS, the position becomes unstable.

Weight-Bearing Bilateral AP Axial Feet: CR Off-Centering Versus Lateral Rotation

The CR is centered between the feet for bilateral AP axial feet. This off-centering of the CR will result in laterally diverged x-rays recording the feet. As explained in **Chapter 1, Table 1.5** in the “off-centering” discussion, which states that at a 40-inch source–image receptor distance (SID), the divergence of x-rays is 2 degrees for every 1 inch off-centered in any direction from the CR, the technologist can estimate the degree of x-ray divergence that is being used to record the feet. This divergence will cause the medial and intermediate cuneiform articulation to be closed and increase the superimposition of the fourth through fifth MT bases (**Fig. 6.28**). The farther apart the feet are from each other, the greater will be the

degree of lateral divergence and the more laterally rotated the resulting projection of the feet will be.

Open Tarsometatarsal (TMT) and Navicular-Cuneiform Joint Spaces

The height of the medial longitudinal arch varies between patients and depends on the health of the supporting ligamentous and muscular structures. If these structures fail, the highest point of the arch descends and the TMT and navicular-cuneiform joint spaces are placed at different angles with the IR. To open these joints on an AP foot projection, the CR angulation must be varied per the degree of medial arch height to align it parallel with them. This is typically accomplished by using a 10- to 15-degree proximal angle, with the lower degree being needed when the medial arch is low and the higher degree needed when the medial arch is high. The simplest method of determining the correct angulation to use regardless of the medial arch height is to align the CR perpendicular to the dorsal surface, as shown in **Fig. 6.29**. This alignment will position the CR parallel with the TMT joints.

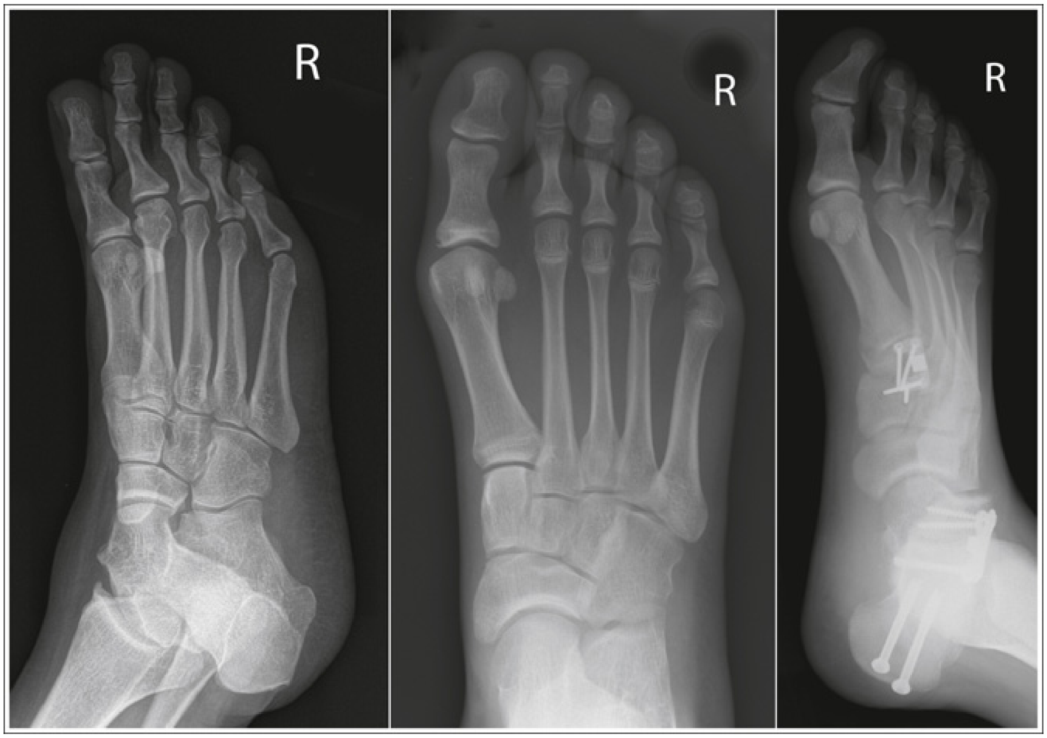
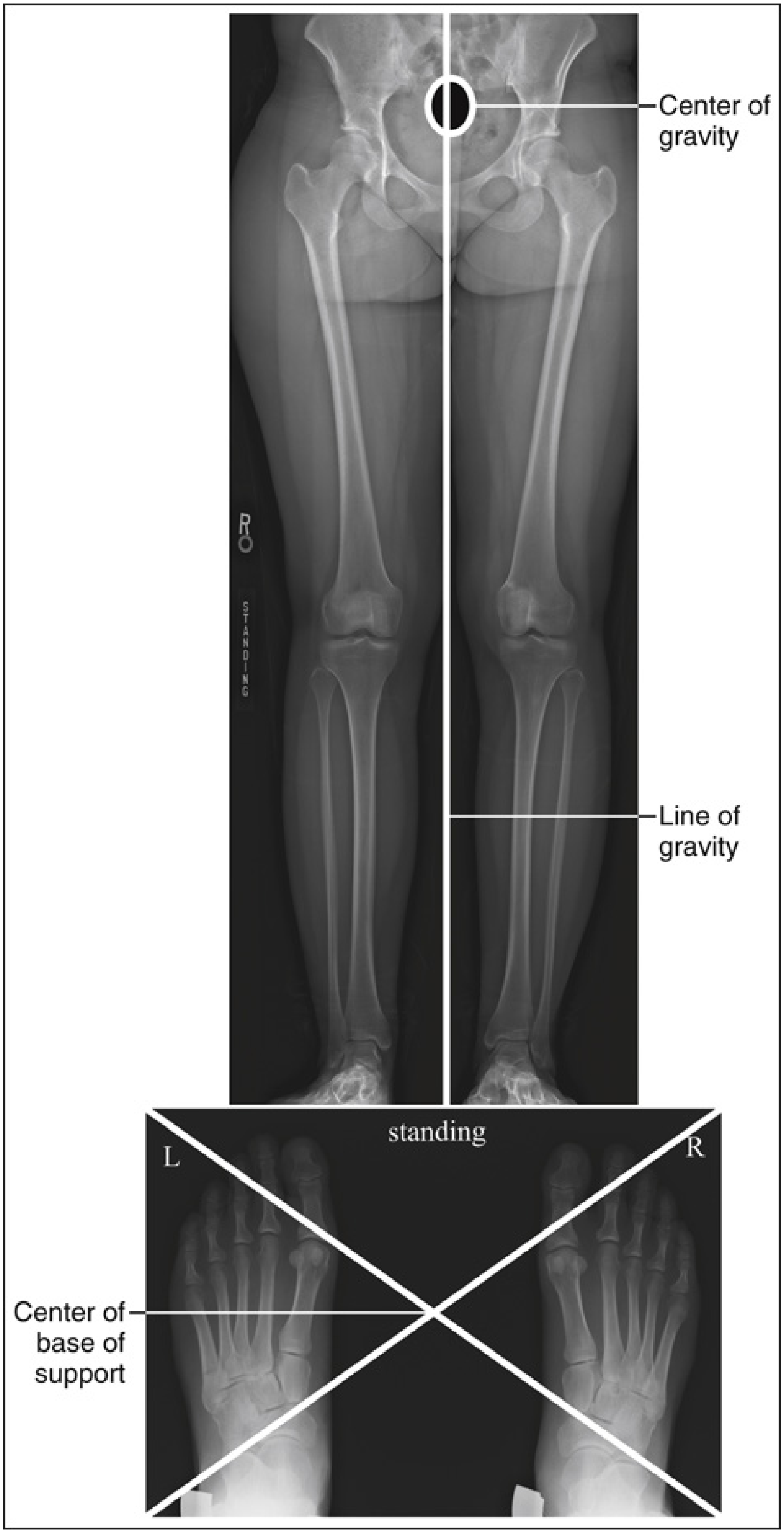


FIGURE 6.25 AP medial oblique, AP, and AP lateral oblique foot projections to compare the changes in the relationship between the MTs and cuneiforms, and the amount of talar and calcaneal superimposition.



Center of gravity
R
STANDING
Line of gravity
standing
L
R
Center of base of support

FIGURE 6.26 Identifying the center of gravity, line of gravity, and base of support center on the standing patient.

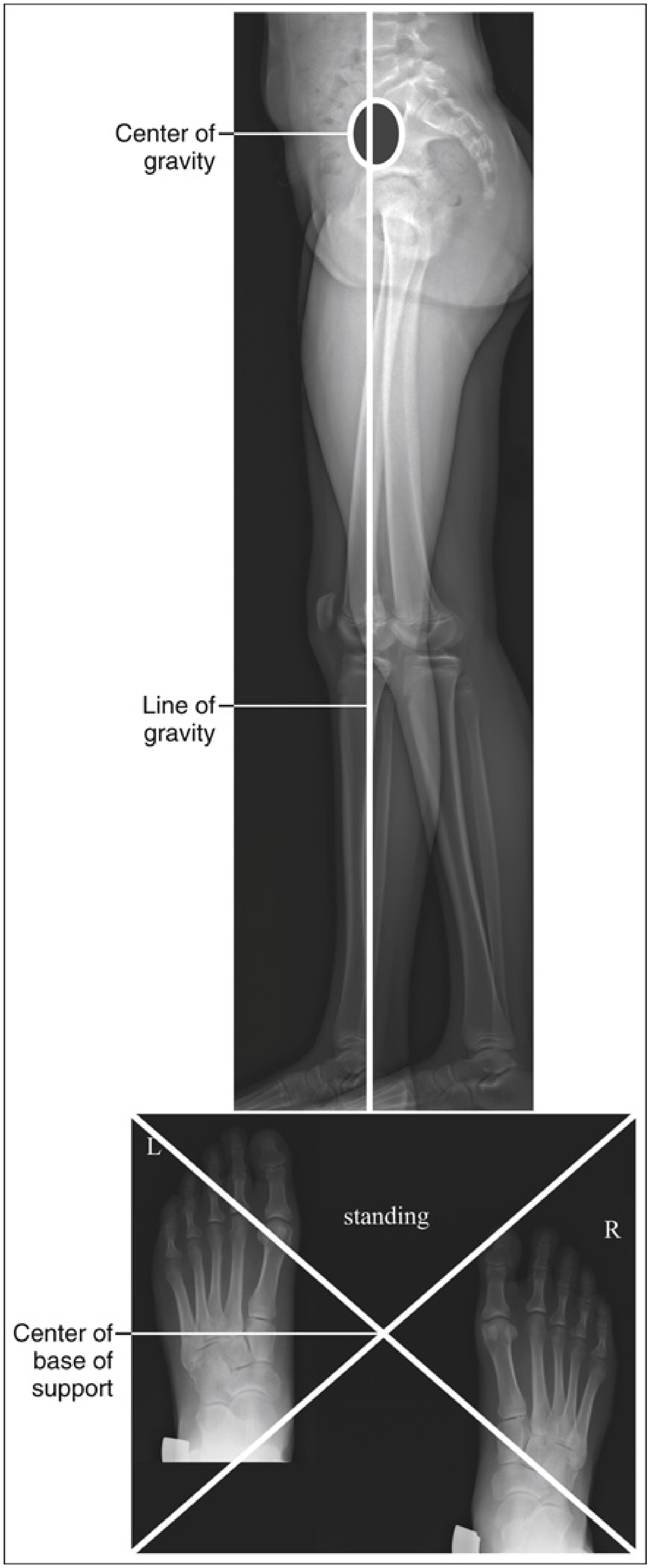

Center of gravity
Line of gravity
L
standing
R
Center of base of support

FIGURE 6.27 Aligning the center of gravity, line of gravity, and base of support center on the standing patient to obtain a state of equilibrium when one foot is positioned in front of the other.

Inaccurate CR Angulation

Employing an inaccurate CR angulation results in obstructed TMT and navicular-cuneiform joint spaces (**Fig. 6.30**).

FIGURE 6.28 Weight-bearing bilateral AP projection of the feet.

FIGURE 6.29 Lateral foot projections demonstrating a high and low medial longitudinal arch to demonstrate proper CR alignment to obtain open TMT and navicular-cuneiform joint spaces.

FIGURE 6.30 AP foot projection taken with poor CR alignment with the TMT and navicular-cuneiform joint spaces.

FIGURE 6.31 Lateral foot projection obtained with the ankle flexed close to 90 degrees with the lower leg and with the ankle extended to demonstrate how the medial longitudinal arch may be affected.

FIGURE 6.32 Lateral foot projections on the same patient demonstrating the effects of weight-bearing versus non–weight-bearing positions on the medial longitudinal arch visualization.

Ankle Flexion

Having the ankle flexed close to a 90-degree angle with the lower leg provides a truer medial longitudinal arch. When the ankle is extended (toes pointed), the longitudinal arch is more elevated, as shown in **Fig. 6.31**, and the CR angle will need to be increased to parallel the TMT joints. This

increase in angulation will result in a more acute CR to IR angle, which will result in greater elongation distortion.

Weight-Bearing AP

The CR angulation needed for the weight-bearing AP foot in many cases will be less than that needed in the non–weight-bearing (**Fig. 6.32**). The added body weight will flatten the medial arch, causing the TMT joints to be at a lower angle with the IR, and require a decrease in CR angulation to parallel them.

Locating the Base of the Third Metatarsal

To place the third MT base in the center of the projection, center the CR to the midline of the foot at a level 0.5 inch (1.25 cm) distal to the fifth MT tuberosity. The fifth MT tuberosity can be palpated along the lateral foot surface, about halfway between the ball of the foot and the calcaneus.

AP Axial Foot Analysis Practice

IMAGE 6.8

Analysis

The TMT joint spaces are closed. The CR was not aligned parallel with these joint spaces.

Correction

Direct the CR 10 to 15 degrees proximally or angle the CR until it is perpendicular with the dorsal surface.

IMAGE 6.9

Analysis

The joint space between the medial and intermediate cuneiforms is closed, the calcaneus demonstrates no talar superimposition, and the MT bases demonstrate decreased superimposition. More pressure was placed on the medial plantar surface than on the lateral surface, resulting in medial foot rotation.

Correction

Rotate the foot laterally until the pressure over the entire plantar surface is equal. The lower leg, ankle, and foot should be aligned for the non–weight-bearing, and the knees and feet positioned at hip width apart for the weight-bearing projection.

Foot: AP Oblique Projection (Medial Rotation)

See **Table 6.6** and Figs. **6.33**–**6.35**.

TABLE 6.6

CR, Central ray; *IR*, image receptor; *MT*, metatarsal.

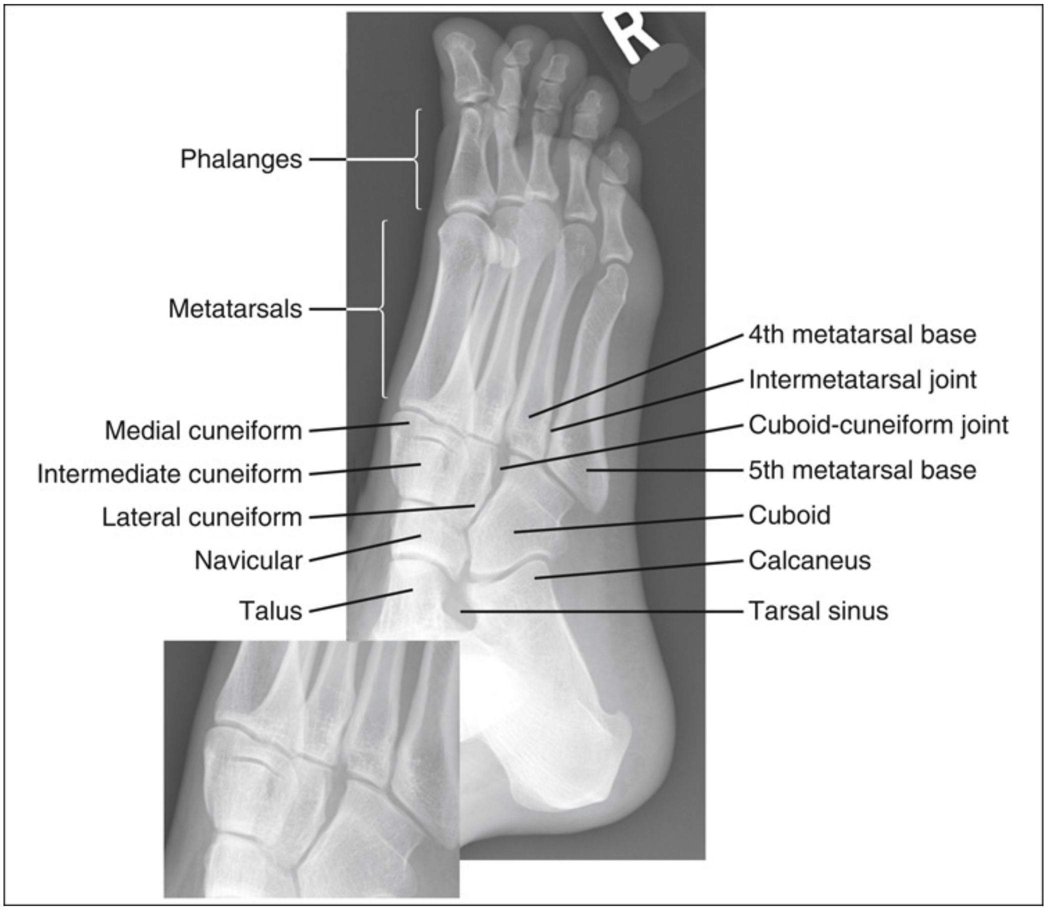


FIGURE 6.33 AP oblique foot projection with accurate positioning in a patient with a high medial longitudinal arch.

FIGURE 6.34 Pediatric AP oblique foot projection with accurate positioning.

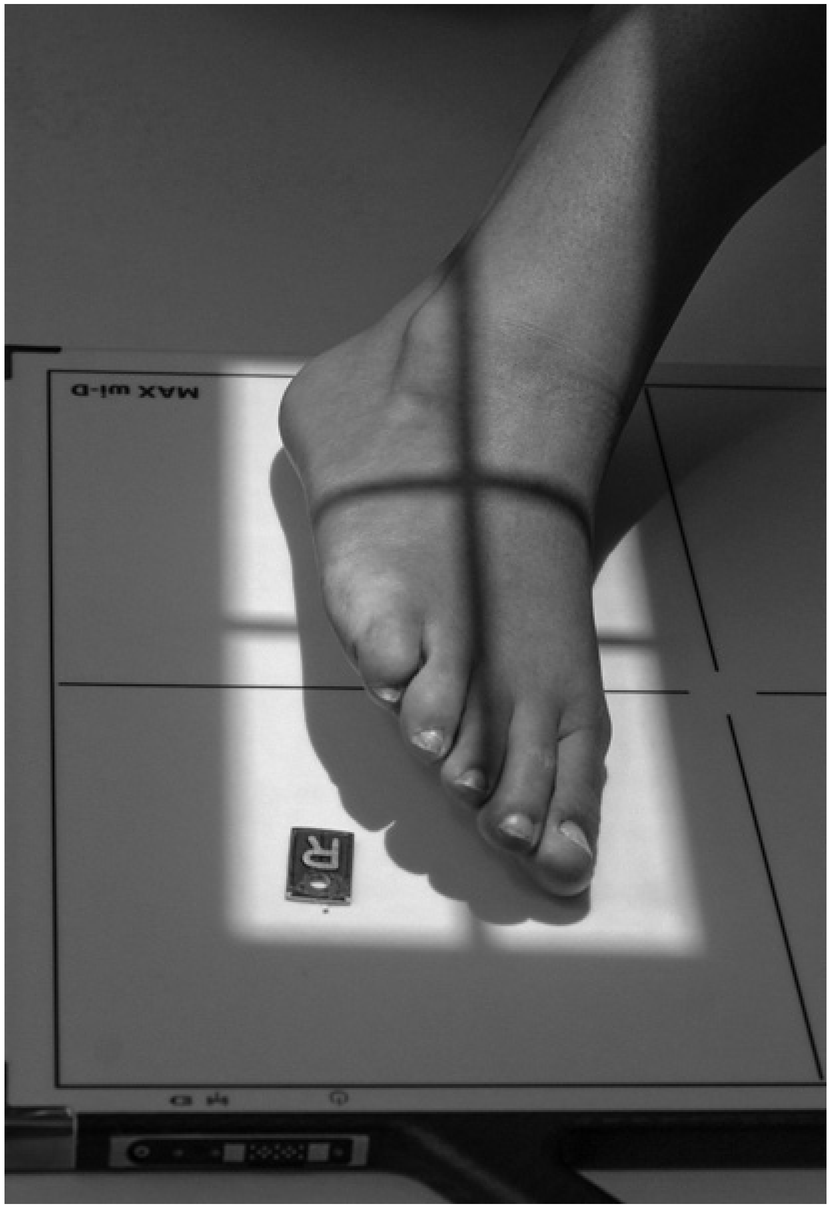


FIGURE 6.35 Proper patient positioning for an AP oblique foot projection.

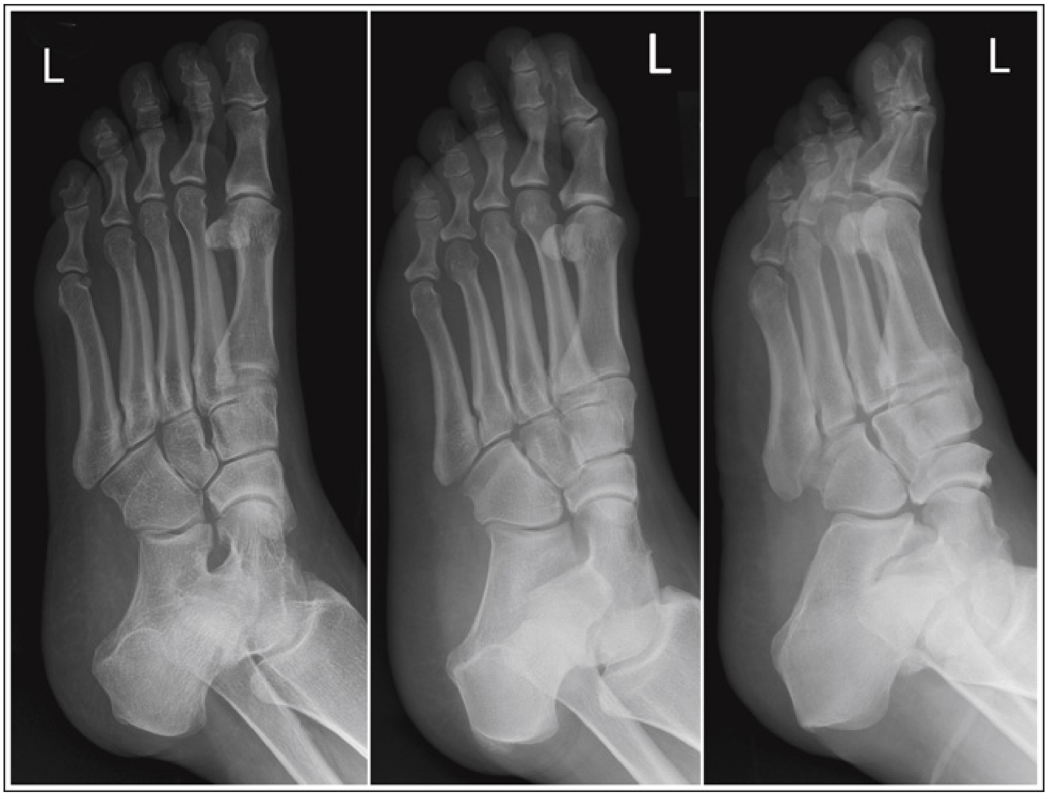


FIGURE 6.36 Accurately positioned AP oblique foot projections taken on patients with a low, average, and high medial longitudinal arch.

Determining Degree of Needed Foot Obliquity

The amount of foot obliquity required to open the cuboid-cuneiform and second through fifth inter-MT joint spaces is dependent on the height of the medial longitudinal arch, with the higher arches requiring more obliquity. **Fig. 6.36** demonstrates an accurately positioned AP oblique foot on a patient with a low, average, and high medial arch. Each demonstrates the required open cuboid-cuneiform and third through fifth inter-MT joint, but each was obtained using a different degree of obliquity, as noted by the amount of first and second MT base superimposition and the amount of space demonstrated between the MT heads. When the foot is rotated

medially, the first MT base rotates beneath the second MT base, with the other MTs following suit, increasing the amount of superimposition and indicating increased obliquity. If the CR was aligned perpendicular to the dorsal surface for the AP foot, as described in **Fig. 6.28**, the degree of angulation determined from this method can be used to indicate the degree of obliquity that is required for the AP oblique foot.

- If the AP foot CR angulation used was around 5 degrees, indicating a low arch, the foot should be placed at 30 degrees of obliquity for the AP oblique foot projection.
- If the CR angulation was around 10 degrees, indicating an average arch, the foot should be placed at 45 degrees of obliquity for the AP oblique foot projection.

FIGURE 6.37 AP oblique foot projection taken with insufficient foot obliquity.

- If the CR angulation was around 15 degrees, indicating a high arch, the foot should be placed at 60 degrees of obliquity for the AP oblique foot projection.

Insufficient Foot Obliquity

The degree of foot obliquity is inadequate for an AP oblique foot projection when the longitudinally running foot joints (cuneiform-cuboid, navicular-cuboid, and third through fifth inter-MT joint spaces) are closed. To determine whether the foot was rotated more or less than the required amount to close these joints, evaluate the inter-MT joint space between the fourth and fifth MTs. If the fourth MT base is superimposing the fifth MT base, the foot was insufficiently rotated (**Fig. 6.37**).

Excessive Foot Obliquity

If the foot was overrotated for an AP oblique foot, the resulting projection demonstrates a closed fourth-fifth inter-MT joint space and the fifth proximal MT in profile and superimposing the fourth MT tubercle (**Fig. 6.38**).

FIGURE 6.38 AP oblique foot projection taken with excessive foot obliquity.

AP Oblique Foot Analysis Practice

IMAGE 6.10

Analysis

The lateral cuneiforms-cuboid, navicular-cuboid, and third through fifth intermetatarsal joint spaces are closed. The fourth MT tubercle is demonstrated without superimposition of the fifth MT. The foot was not medially rotated enough.

Correction

Increase the degree of medial foot obliquity.

IMAGE 6.11

Analysis

The lateral cuneiforms-cuboid, navicular-cuboid, and inter-MT joint spaces are closed, and the fifth proximal MT is superimposed over the fourth MT tubercle. The foot was overrotated.

Correction

Decrease the amount of medial foot obliquity.

Foot: Lateral Projection (Mediolateral and Lateromedial)

See **Table 6.7** and Figs. **6.39**–**6.41**.

Anterior Pretalar and Posterior Pericapsular Fat Pads

Two soft tissue structures located around the foot and ankle may indicate joint effusion and injury: the anterior pretalar fat pad and posterior pericapsular fat pad. The anterior pretalar fat pad is visible anterior to the ankle joint and rests next to the neck of the talus (**Fig. 6.42**). Surrounding the ankle joint is a fibrous, synovium-lined capsule attached to the borders of the tibia, fibula, and talus. On injury or disease invasion, the synovial membrane secretes synovial fluid, resulting in distention of the fibrous capsule. Anterior fibrous capsule distention results in displacement of the anterior pretalar fat pad. Because neither the fibrous capsule nor the ankle ligaments can be detected on radiography, displacement of this fat pad indicates joint effusion and the possibility of underlying injuries.

The posterior fat pad is positioned within the indentation formed by the articulation of the posterior tibia and talar bones (see **Fig. 6.42**). This fat pad is displaced in the same manner as the anterior pretalar fat pad, although it is less sensitive and requires more fluid evasion to be displaced. In most cases, when a patient is supine and relaxed, the leg rests in external rotation with the foot in plantar flexion. Plantar flexion results in a forced flattening of the anterior pretalar fat pad, reducing its usefulness in the detection of joint effusion.

TABLE 6.7

CR, Central ray; *IR*, image receptor; *MT*, metatarsal.

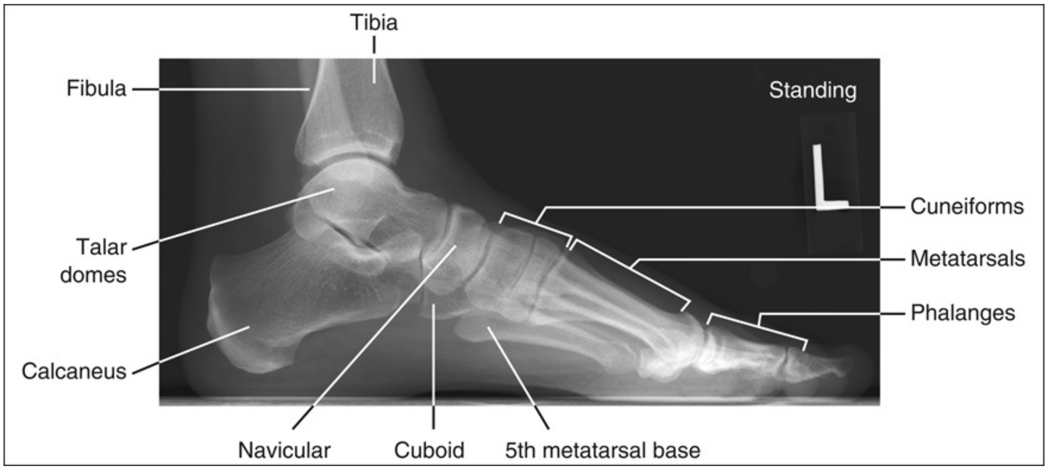


FIGURE 6.39 Mediolateral foot projection with accurate positioning.

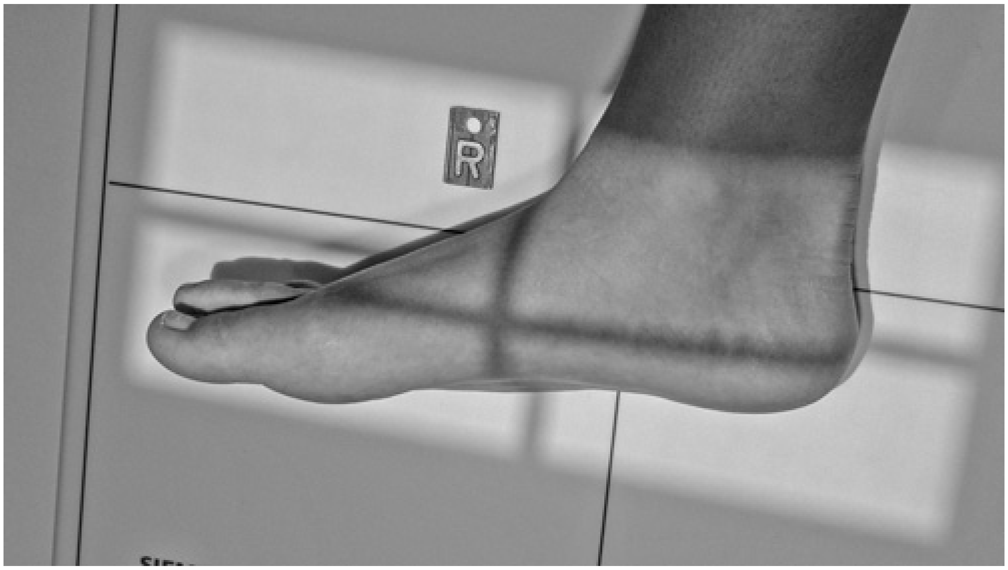


FIGURE 6.40 Proper patient positioning for a lateral foot projection.

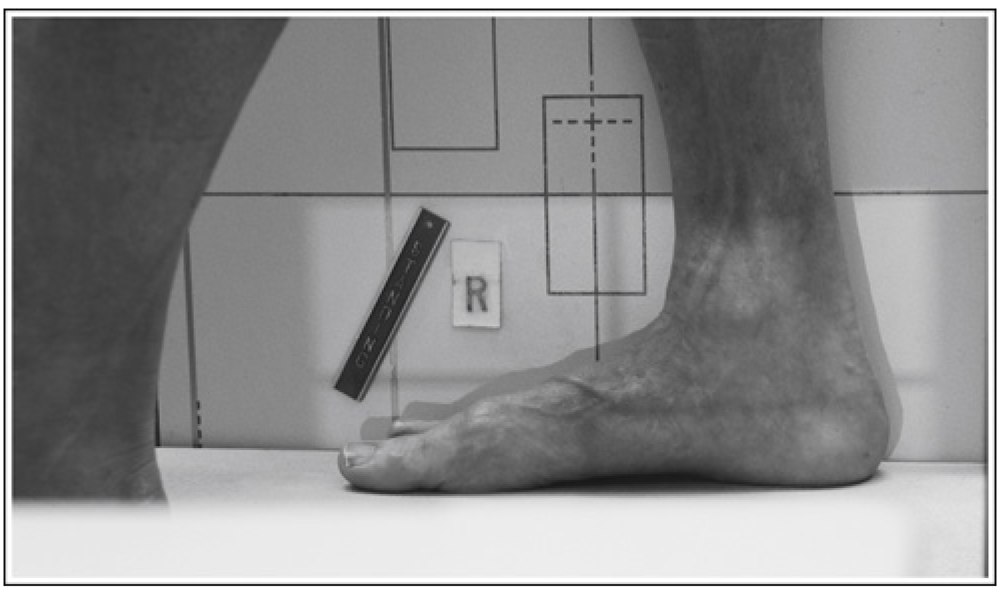


FIGURE 6.41 Proper patient positioning for a weight-bearing lateral foot projection.

Non–Weight-Bearing: Lower Leg and Foot Alignment

Appropriately aligning the lower leg and foot at 90 degrees from each other places the tibiotalar joint in a neutral position and tightens the ligament and muscle structures that will help prevent foot rotation. **Fig. 6.43** demonstrates non–weight-bearing lateral foot projections obtained in dorsiflexion and plantar flexion of the same patient. Note that the plantar-flexed projection in comparison with the dorsiflexed projection demonstrates rotation and a higher-appearing medial arch. To obtain an accurate lateral foot on a patient who is unable to dorsiflex, the knee needs to be slightly flexed and an immobilization support placed beneath it to elevate it the needed amount to place the plantar surfaces of the heel and forefoot perpendicular with the IR (**Fig. 6.44**).

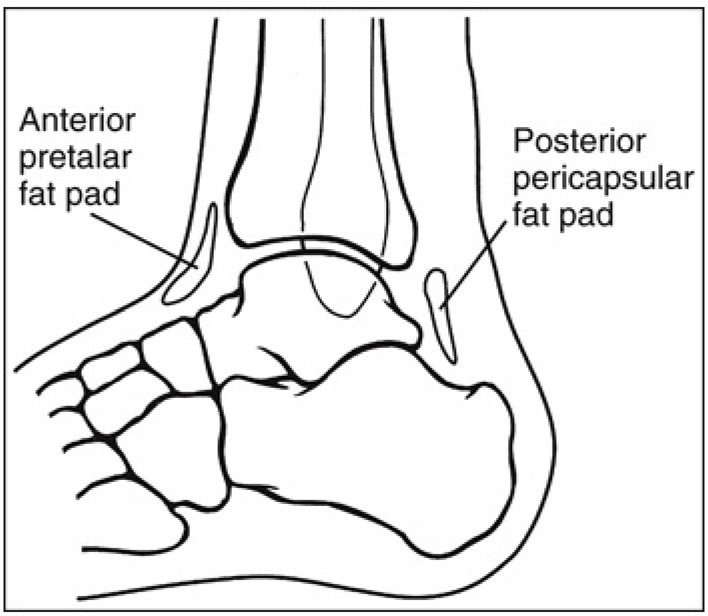


FIGURE 6.42 Location of fat pads on lateral foot and ankle projections.

Weight-Bearing: Lower Leg and Foot Alignment

Weight-bearing lateral feet projections are obtained to demonstrate how the feet and ankle react to having the patient's weight on them. The amount of the weight that is placed on each foot is determined by the placement of the COG in reference to the BOS center as discussed above (see **Fig. 6.26**). On weight-bearing lateral feet projections, the angle formed between the lower leg and foot may be used to estimate where the COG was placed in the BOS and the amount of pressure from the body's weight that was applied to the affected foot.

FIGURE 6.43 Lateral foot projections obtained with the foot dorsiflexed *(top)* and plantar flexed *(bottom)* of the same patient.

FIGURE 6.44 Accurately positioned lateral foot projection obtained with the patient in plantar flexion.

- *When the affected foot is at an 80- to 85-degree angle with the lower leg,* the unaffected foot is positioned just in front of the affected foot, and the COG is centered above the BOS center, the patient's weight is evenly distributed between both feet (**Fig. 6.45**). This gait is the most recommended positioning, as it most commonly mocks the patient's natural gait.
- *When the affected foot is at a 90-degree angle with the lower leg,* the unaffected foot is lightly resting on its forefoot or toes, and the COG is centered behind the BOS center, the patient's weight is primarily on the affected foot (**Fig. 6.46**).

- *When the affected foot is at a greater than 90-degree angle with the lower leg*, the unaffected foot is positioned too far behind the affected foot, and the COG is centered behind the BOS center, the patient's weight is primarily on the unaffected foot (**Fig. 6.47**).
- *When the affected foot is at a less than 80-degree angle with the lower leg*, the unaffected foot is positioned too far in front of the affected foot, and the COG is centered in front of the BOS center, the patient's weight is primarily on the unaffected foot (**Fig. 6.48**).

FIGURE 6.45 Weight-bearing lateral foot projection obtained with the weight evenly distributed between the feet and COG centered above the BOS center.

Lower Leg Positioning: Proximal Talar Dome Alignment

The domes of the talus are formed by the most medial and lateral aspects of the talar's trochlear surface and appear as domed structures that articulate with the tibia on lateral foot projections. When the lower leg is aligned parallel with the IR, the proximal aspects of the talar domes are aligned (**Fig. 6.49**). When viewing a lateral foot projection that demonstrates one of

the talar domes proximal to the other, evaluate the height of the medial arch, the amount of distal fibula and distal tibia superimposition, and the degree of narrowing or widening of the talocalcaneal joint to determine which dome is the proximal dome and how to adjust the lower leg to reposition.

The height of the medial arch can be determined by measuring the amount of cuboid demonstrated posterior to the navicular bone. The average lateral foot projection demonstrates approximately half (0.5 inch [1.25 cm]) of the cuboid posteriorly to the navicular, as shown in **Fig. 6.50**. Because the bones that form the foot arch are held in position by ligaments and tendons, weakening of these tissues may result in a decreased or low arch. On a lateral foot projection, this decrease in medial arch height is demonstrated as a decrease in the amount of cuboid demonstrated posterior to the navicular bone. **Fig. 6.51** shows a lateral foot of a patient with a low medial arch and less than half (0.25 inch [0.6 cm]) of cuboid posterior to the navicular bone, whereas **Fig. 6.52** shows a patient with a high medial arch and more than half (0.75 inch [2 cm]) of cuboid posterior to the navicular bones.

When the lower leg is positioned parallel with the IR for a lateral foot projection, the fibula projects more distally than the distal medial tibia by about 0.25 inch (0.6 cm; **Fig. 6.53**). When the lower leg is tilted with the IR, this relationship changes. If the proximal lower leg is farther from the IR than the distal lower leg, the distal fibula will be more proximal and the distal tibia will be more distal to this relationship. If the distal lower leg is farther from the IR than the proximal lower leg, the distal fibula will be more distal and the distal tibia more proximal to this relationship.

Positioning the lower leg parallel with the IR can be problematic for patients with thicker upper thighs or those unable to extend their knee, as these cause the distal lower leg to tilt toward the IR. For these patients, the

foot and IR are elevated with a sponge until the lower leg is brought parallel with the IR.

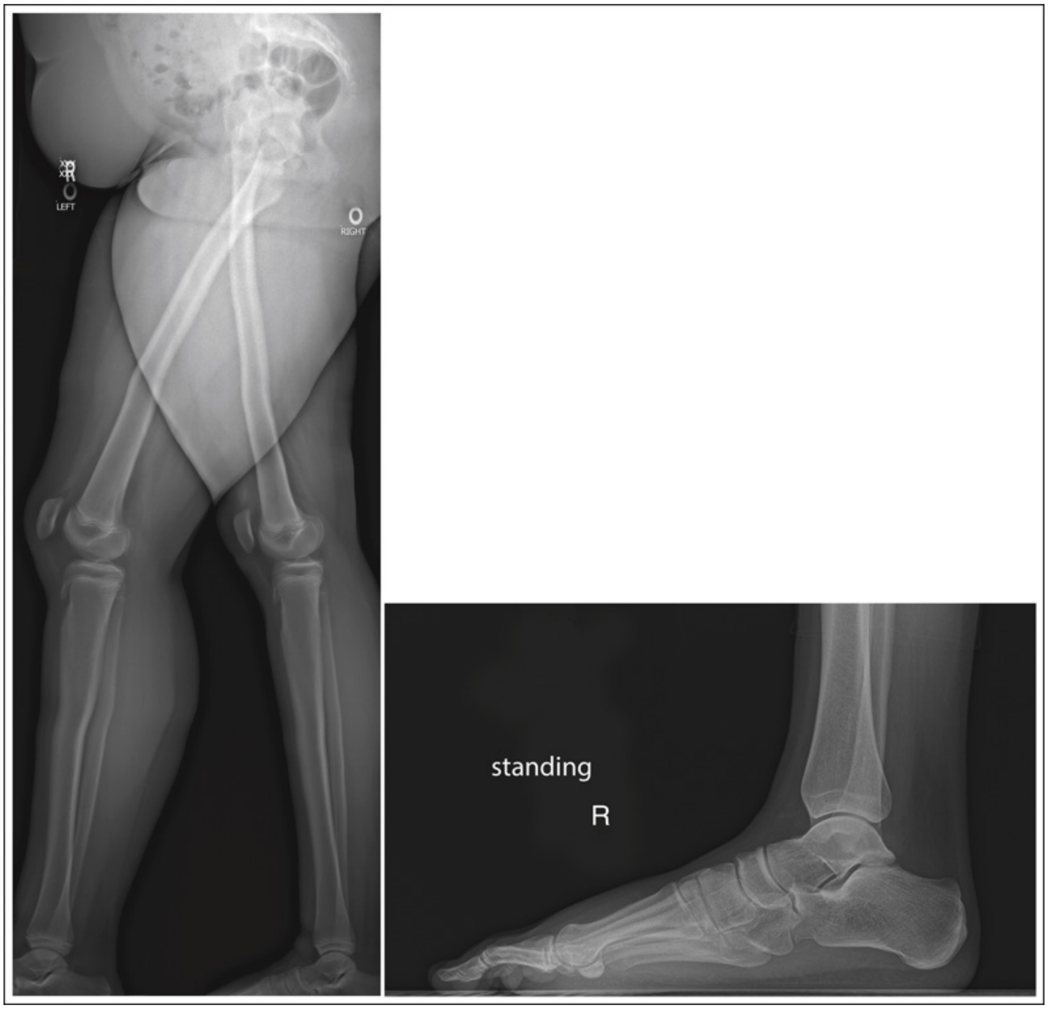


FIGURE 6.46 Weight-bearing lateral foot projection obtained with the affected lower leg and ankle at a 90-degree angle with each other and all of the patient's weight on the affected foot. The unaffected foot is resting on forefoot.

FIGURE 6.47 Weight-bearing lateral foot projection obtained with most of the weight on the unaffected foot that is positioned behind the affected foot.

Non–Weight-Bearing: Elevated Proximal Lower Leg

If the proximal lower leg is elevated farther from the IR than the distal lower leg for a lateral foot projection (**Fig. 6.54**):

- The lateral talar dome is demonstrated proximally to the medial talar dome.
- Less than half (0.5 inch [1.25 cm]) of the cuboid is demonstrated posteriorly to the navicular bone if the patient has an average medial arch.
- The distal fibula is less than 0.25 inch (0.6 cm) distal to or is proximal to the distal medial tibia.

- The talocalcaneal and tibiotalar joint spaces are closed on the resulting projection.

To reposition, the proximal lower leg needs to be depressed by extending the knee, or the distal lower leg needs to be elevated on a sponge.

Non–Weight-Bearing: Elevated Distal Lower Leg

If the distal lower leg is elevated above the proximal lower leg for a lateral foot projection (**Fig. 6.55**):

- The lateral talar dome is demonstrated distally to the medial talar dome.

FIGURE 6.48 Weight-bearing lateral foot projection with the weight on the unaffected foot, which is positioned in front of the affected foot.

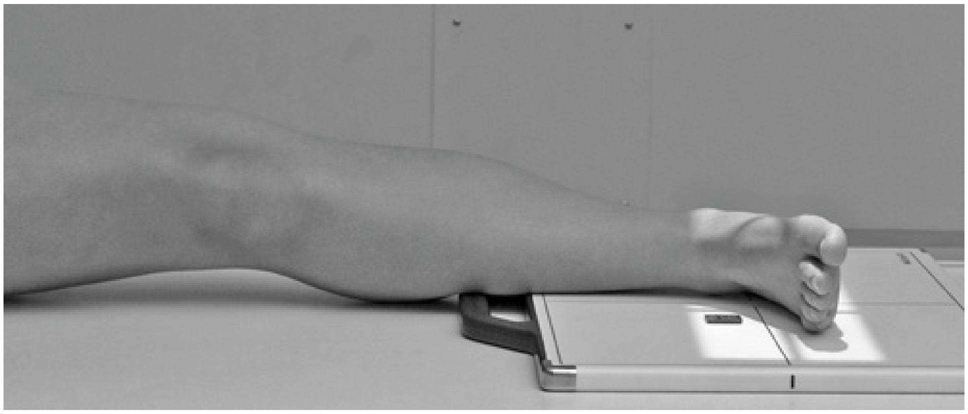


FIGURE 6.49 Accurate positioning of the lower leg for a recumbent lateral foot projection.

FIGURE 6.50 Lateral foot projection of a patient with an average medial longitudinal arch.

FIGURE 6.51 Lateral foot projection of a patient with a low medial longitudinal arch.

FIGURE 6.52 Lateral foot projection of a patient with a high medial longitudinal arch.

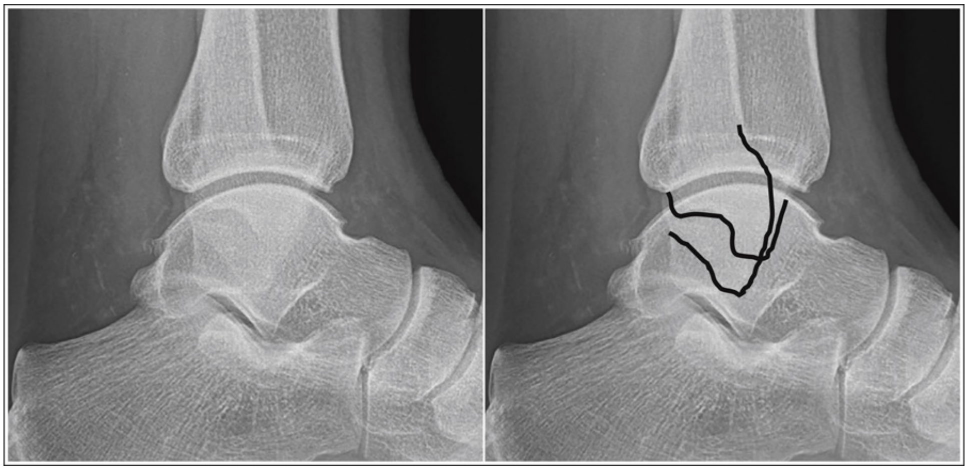


FIGURE 6.53 Location of the distal fibula and distal medial tibia on an accurately positioned lateral foot projection.

- More than one-half (0.5 inch [1.25 cm]) of the cuboid is demonstrated posteriorly to the navicular bone if the patient has an average medial arch.
- The distal fibula is greater than 0.25 inch (0.6 cm) distal to the distal medial tibia.
- The talocalcaneal joint is open.
- The tibiotalar joint is closed on the resulting projection.

To reposition, the distal lower leg needs to be depressed. If this is not possible, the CR can be angled caudally to align it with the tibiotalar joint space.

Side-to-Side Alignment of Ankles and Lower Legs

Positioning the feet hip width apart provides a larger BOS and positions the proximal talar domes at the same horizontal level. **Fig. 6.56** demonstrates a weight -bearing bilateral AP ankle projection that shows proper side-to-side alignment of the ankles and parallelism of the lower leg that should be seen from the front when positioning for the weight-bearing mediolateral foot

projection, with the exception that one of the ankles would be in front of the other. In this positioning, the horizontal CR will run parallel with the proximal talar domes and results in their accurate alignment on the resulting projection.

FIGURE 6.54 Lateral foot projection taken with the proximal lower leg elevated.

FIGURE 6.55 Lateral foot projection taken with the distal lower leg elevated.

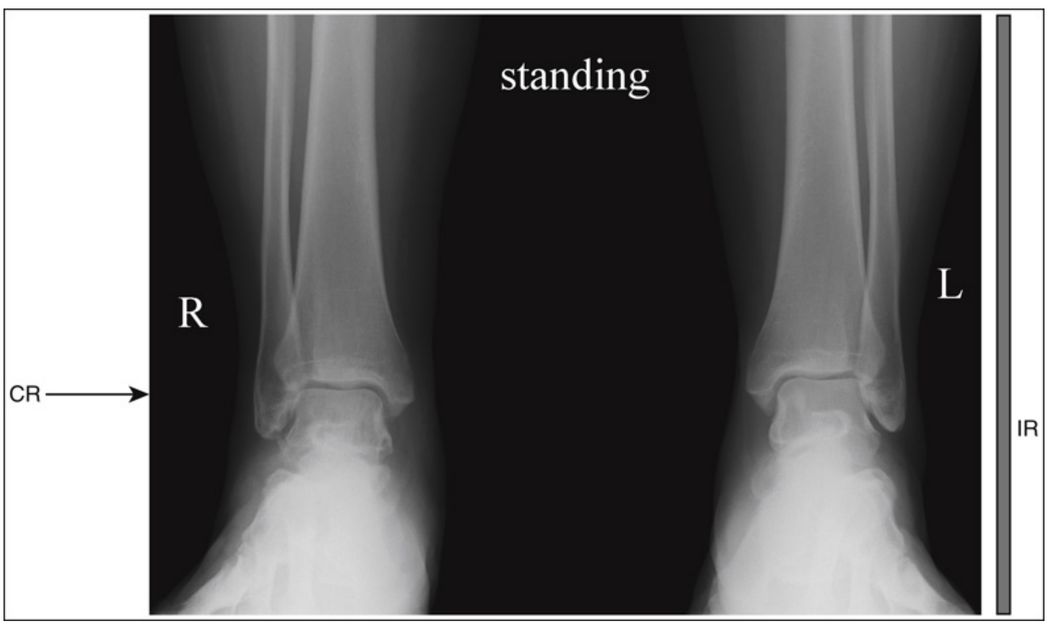


FIGURE 6.56 Weight-bearing bilateral AP ankle projection to demonstrate proper feet separation and lower leg parallelism to use for the mediolateral projection.

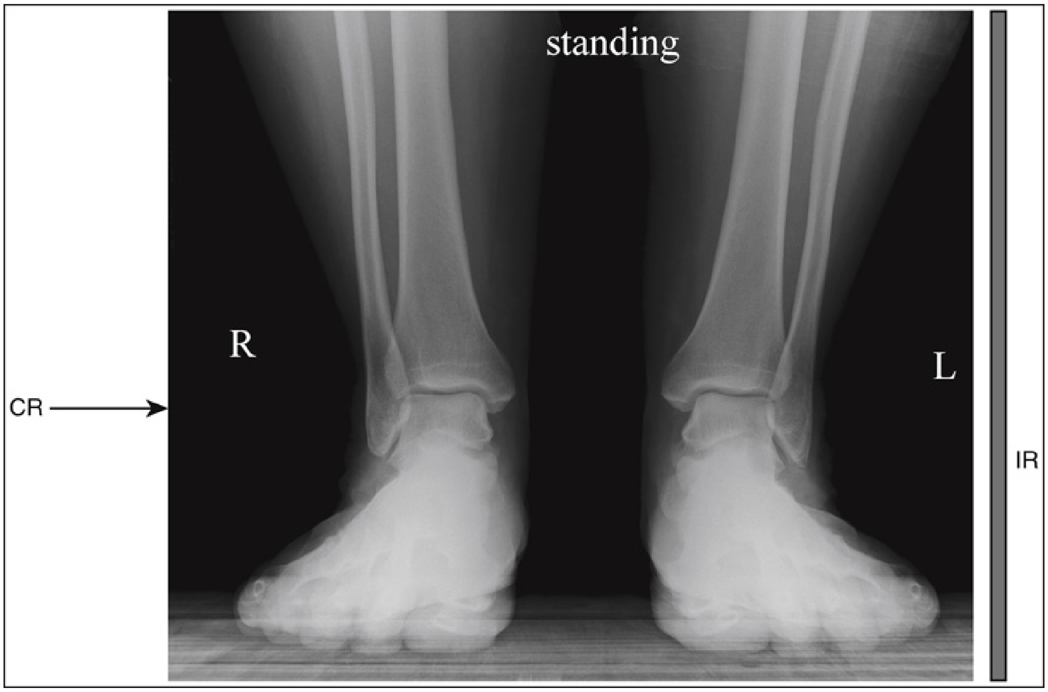


FIGURE 6.57 Weight-bearing bilateral AP ankle projection showing the feet positioned too close together and the lower legs not parallel.

Weight-Bearing: Distal Lower Leg Positioned Farther From IR Than Proximal Lower Leg

If the feet are positioned closer than hip width apart, the patient demonstrates a varus knee condition (see **Fig. 6.156**), or the COG is shifted from the BOS center toward the affected foot for a weight-bearing lateral foot, the ankle will be everted, the proximal lower leg will be positioned closer to the IR than the distal lower leg, and the foot may be laterally rotated (**Fig. 6.57**). The resulting projection will demonstrate the medial talar dome proximally to the lateral talar dome, more than half of the cuboid demonstrated posteriorly to the navicular bone if the patient has an average medial longitudinal arch, the fibula demonstrated more than 0.5 inch (0.6

cm) distally to the distal tibia, an open talocalcaneal joint, and a closed tibiotalar joint (**Fig. 6.58**).

Weight-Bearing: Proximal Lower Leg Positioned Farther From IR Than Distal Lower Leg

If the feet are positioned farther than hip width apart, the patient demonstrates a valgus knee condition (see **Fig. 6.155**), or the COG is shifted from the BOS center toward the unaffected foot for a weight-bearing lateral foot, the ankle may be inverted with the proximal lower leg positioned farther from the IR than the distal lower leg, and the foot medially rotated. The resulting projection demonstrates the lateral talar dome proximally to the medial talar dome, less than one-half of the cuboid posteriorly to the navicular bone if the patient has an average medial longitudinal arch, the distal fibula demonstrated less than 0.25 inch (0.6 cm) distally to or demonstrated proximally to the distal medial tibia, and closed talocalcaneal and tibiotalar joint spaces (**Fig. 6.59**).

image

FIGURE 6.58 Weight-bearing mediolateral ankle projection obtained with the proximal lower leg positioned closer to the IR than the distal lower leg, causing ankle inversion.

FIGURE 6.59 Weight-bearing mediolateral foot/ankle projection obtained with the proximal lower leg positioned farther from the IR than the distal lower leg, causing ankle eversion.

FIGURE 6.60 Accurate positioning of the lateral foot surface for a non–weight-bearing lateral foot projection.

Leg Rotation: Anterior and Posterior Alignment of the Talar Domes

The anterior and the posterior aspects of the talar domes are aligned on a lateral foot projection when the lateral foot surface is aligned parallel with the IR and even pressure with the IR is placed across the entire lateral surface (**Fig. 6.60**). When viewing a lateral foot projection that demonstrates one of the talar domes anterior to the other, evaluate the position of the fibula in relation to the tibia to determine how to reposition the patient.

External Leg Rotation

If the leg is externally rotated more than needed to place the lateral foot surface parallel with the IR for a lateral foot projection, placing more surface pressure at the forefoot (**Fig. 6.61**), the lateral talar dome is demonstrated posterior to the medial talar dome and the anterior fibula is posterior to the mid-tibia (**Fig. 6.62**).

Internal Leg Rotation

If the leg is not externally rotated enough to place the lateral foot surface parallel with the IR for a lateral foot projection, placing more surface pressure at the heel (**Fig. 6.63**), the lateral talar dome is demonstrated anterior to the medial talar dome and the anterior fibula is demonstrated anteriorly to the mid-tibia (**Fig. 6.64**).

image

FIGURE 6.61 Poor lateral foot positioning with the calcaneus elevated (leg externally rotated).

Weight-Bearing Lateromedial Projection

A standing lateromedial foot projection is accomplished by placing the IR against the medial aspect of the foot and aligning the lateral foot surface parallel with the IR, as shown in **Fig. 6.65**. The resulting projection should meet all the analysis requirements listed for the mediolateral foot projection. The most common misposition for the standing lateromedial projection of the foot shows the medial talar dome positioned anterior to the lateral dome and the anterior fibula positioned too posteriorly to the mid-tibia (**Fig. 6.66**). This misposition is a result of aligning the medial foot surface parallel with the IR, as shown in **Fig. 6.67**, rather than the lateral surface. When such a projection is obtained, internally rotate the leg until the lateral foot surface is parallel with the IR.

FIGURE 6.62 Non–weight-bearing lateral foot projection taken with the leg externally rotated.

FIGURE 6.63 Poor lateral foot positioning with the calcaneus depressed (leg internally rotated).

FIGURE 6.64 Non–weight-bearing lateral foot projection taken with the leg internally rotated.

FIGURE 6.65 Weight-bearing lateromedial foot projection with accurate positioning.

FIGURE 6.66 Weight-bearing lateromedial foot projection taken with the leg externally rotated and medial foot surface aligned parallel with the IR as shown in **Fig. 6.67**.

image

FIGURE 6.67 Weight-bearing lateromedial foot projection.

Lateral Foot Analysis Practice

image

IMAGE 6.12

Analysis

The medial talar dome is positioned anterior to the lateral dome. The leg was externally rotated. The foot is in plantar flexion.

Correction

Internally rotate the leg until the lateral surface of the foot is parallel with the IR and dorsiflex the foot to a 90-degree angle with the lower leg.

image

IMAGE 6.13 Non–weight-bearing.

Analysis

The lateral talar dome is positioned anterior to the medial talar dome. The foot was internally rotated.

Correction

Externally rotate the leg until the lateral surface of the foot is parallel with the IR.

image

IMAGE 6.14 Non–weight-bearing.

Analysis

The lateral talar dome is proximal to the medial talar dome, less than half of the cuboid is demonstrated posteriorly to the navicular bone, and the talocalcaneal and tibiotalar joint spaces are closed. The proximal lower leg is elevated farther from the IR than the distal lower leg. There is a slight amount of plantar flexion.

Correction

Depress the proximal lower leg by extending the knee or elevate the distal lower leg on a sponge. Dorsiflex the foot to a 90-degree angle with the lower leg.

Calcaneus: Axial Projection (Plantodorsal)

See **Table 6.8** and Figs. **6.68**–**6.70**.

Opening the Talocalcaneal Joint Space

The talocalcaneal joint space is demonstrated as an open space as long as the CR is aligned parallel with it. When the plantar foot surface is positioned vertically, the talocalcaneal joint space is placed at a 40-degree angle with the plane of the IR and the 40-degree proximal CR angulation that is used is parallel aligned with it. This setup also aligns the CR nearly

perpendicular to the long axis of the calcaneal tuberosity, but because the tuberosity is tilted in relation to the IR, elongation of the tuberosity is present.

image

FIGURE 6.68 Axial calcaneal projection with accurate positioning.

TABLE 6.8

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor; *MT*, metatarsal.

Excessive Dorsiflexion

If the foot is dorsiflexed beyond the vertical position and a 40-degree CR angulation is used, the resulting projection will demonstrate a closed talocalcaneal joint space, and because the CR is aligned closer to perpendicular with the long axis of the tuberosity, the tuberosity will demonstrate less foreshortening (**Figs. 6.71** and **6.72**).

Insufficient Dorsiflexion

Most patients that have sustained trauma to the calcaneal tuberosity are unable to dorsiflex their foot to 90 degrees with the lower leg. On such a patient, if the projection is obtained with the foot in plantar-flexion and a 40-degree CR angulation, the talocalcaneal joint space will be obscured, and because the CR is aligned closer to parallel with the long axis of the tuberosity, the tuberosity will demonstrate excessive foreshortening (**Figs. 6.73** and **6.74**).

image

FIGURE 6.69 Proper axial calcaneal projection positioning.

image

FIGURE 6.70 Illustration to demonstrate how placing the foot at a 90-degree angle with the IR and using a 40-degree CR angulation will result in the CR being aligned parallel with the talocalcaneal joint space, causing it to be open.

image

FIGURE 6.71 Illustration to demonstrate how foot dorsiflexion with a 40-degree CR angle fails to align the CR parallel with the talocalcaneal joint space, causing the talocalcaneal joint space to be closed on the resulting axial calcaneal projection.

image

FIGURE 6.72 Axial calcaneal projection taken with poor CR and talocalcaneal joint alignment. The CR to foot angle was larger than 40 degrees.

image

FIGURE 6.73 Illustration of CR alignment with the talocalcaneal joint and calcaneal tuberosity when the foot is in plantar flexion.

image

FIGURE 6.74 Axial calcaneal projection taken with poor CR and talocalcaneal joint alignment.

To open the talocalcaneal joint on a patient that is unable to adequately dorsiflex, increase the CR angulation until it aligns with the fifth MT base and the point of the distal fibula (**Figs. 6.75** and **6.76**). If the angle created between the CR and IR is very acute, the tuberosity will demonstrate excessive elongation (**Fig. 6.77**). An alternate method to demonstrate the tuberosity when the foot is plantar-flexed is to elevate the distal lower leg, bringing the plantar surface closer to perpendicular with the IR, and angle the CR until it is closer to perpendicular with the tuberosity; however, this will cause increased magnification the farther the heel is positioned away from the IR. If the magnification is unacceptable, a second projection taken to better demonstrate the tuberosity may be obtained using a lower CR angulation. This projection will not demonstrate an open talocalcaneal joint.

Calcaneal Rotation and Tilting

If the leg is internally rotated or the ankle inverted, the first and second MTs are demonstrated medially. If the leg is externally rotated or the ankle everted, the fourth and fifth MTs are demonstrated laterally (**Fig. 6.78**).

image

FIGURE 6.75 To open the talocalcaneal joint space on a patient who cannot dorsiflex, align the CR parallel with the fifth MT base and the point of the distal fibula.

image

FIGURE 6.76 Axial and lateral calcaneal projections on patient with calcaneal fracture.

image

FIGURE 6.77 Axial calcaneal projection obtained using the method demonstrated in **Fig. 6.75**.

image

FIGURE 6.78 Axial calcaneal projection taken with external ankle rotation.

Axial Calcaneal Analysis Practice

image

IMAGE 6.15

Analysis

The fourth and fifth MTs are demonstrated on the lateral aspect of the foot. The ankle was externally rotated, or the foot was everted.

Correction

Internally rotate the leg until the ankle is in an AP projection, or bring the foot to a neutral position without eversion.

Calcaneus: Lateral Projection (Mediolateral)

See **Table 6.9** and **Figs. 6.79** and **6.80**.

Foot Dorsiflexion for Trauma Calcaneus

Trauma to the calcaneal tuberosity prevents most patients from being able to dorsiflex their foot. To obtain an accurate lateral calcaneus on a patient that is unable to dorsiflex, the leg may be elevated the needed amount to place the plantar surfaces of the heel and forefoot perpendicular with the IR. **Fig. 6.81** demonstrates two lateral calcaneal projections obtained on a patient with a fractured tuberosity. Note how the fracture is demonstrated differently on these two projections, with only a very small difference in positioning.

Proximal Lower Leg Elevated

If the proximal lower leg is elevated for the lateral calcaneus, the resulting projection will demonstrate the lateral talar dome proximal to the medial talar dome, less than one-half (0.5 inch [1.25 cm]) of the cuboid posterior to the navicular bone if the patient has an average medial arch, the distal fibula less than 0.25 inch (0.6 cm) distal to or the distal fibula proximal to the distal medial tibia, and closed talocalcaneal and tibiotalar joint spaces (**Fig.**

6.82). To reposition, the distal lower leg needs to be elevated or the proximal lower leg depressed by extending the knee.

Elevated Distal Lower Leg

If the distal lower leg is elevated for a lateral calcaneus, the resulting projection will demonstrate the lateral talar dome is distal to the medial talar dome, more than one-half (0.5 inch [1.25 cm]) of the cuboid is demonstrated posterior to the navicular bone if the patient has an average medial arch, the distal fibula is greater than 0.25 inch (0.6 cm) distal to the distal medial tibia, the talocalcaneal joint is open, and the tibiotalar joint is closed (**Fig. 6.83**).

TABLE 6.9

CR, Central ray; *IR*, image receptor.

image

FIGURE 6.79 Lateral calcaneal projection with accurate positioning.

image

FIGURE 6.80 Proper patient positioning for the lateral calcaneal projection.

image

FIGURE 6.81 Lateral calcaneal projection demonstrating a calcaneal fracture.

image

FIGURE 6.82 Lateral calcaneal projection taken with the proximal lower leg elevated.

image

FIGURE 6.83 Lateral calcaneal projection taken with the distal lower leg elevated.

image

FIGURE 6.84 Lateral calcaneal projection taken with the leg externally rotated.

External Leg Rotation

If the leg is externally rotated more than needed to place the lateral foot surface parallel with the IR, applying more surface pressure at the forefoot (see **Fig. 6.61**), the lateral talar dome is demonstrated posterior to the medial talar dome and the anterior fibula is demonstrated posterior to the mid-tibia on the resulting projection (**Fig. 6.84**).

Internal Leg Rotation

If the leg is internally rotated more than needed to place the lateral foot surface parallel with the IR, applying more surface pressure at the heel (see **Fig. 6.63**), the lateral talar dome is demonstrated anterior to the medial talar dome and the anterior distal fibula is aligned anteriorly to the mid-tibia on the resulting projection (**Fig. 6.85**).

image

FIGURE 6.85 Lateral calcaneal projection taken with the leg internally rotated.

Lateral Calcaneal Analysis Practice

image

IMAGE 6.16

Analysis

The medial talar dome is positioned posterior to the lateral dome, as indicated by the anterior distal fibula being aligned anteriorly to the mid-tibia. The leg was internally rotated.

Correction

Externally rotate the leg until the lateral foot surface is positioned parallel with the IR.

IMAGE 6.17

Analysis

The lateral talar dome is positioned proximal and anterior to the lateral dome. The lower leg was not parallel with the IR (knee elevated) and the foot was internally rotated.

Correction

Straighten the knee, and if needed, elevate the distal lower leg until the lower leg is parallel with the IR. Externally rotate the leg until the lateral surface of the foot is parallel with the IR.

Ankle: AP Projection

See **Table 6.10** and Figs. **6.86**–**6.88**.

Ruptured Ligament Variation

Contrary to the analysis in **Table 6.10**, if the patient has a ruptured ligament, the lateral mortise may also be demonstrated as an open space (**Fig. 6.89**). Such a projection is only acceptable when the medial mortise is also open because it indicates that the projection was obtained without rotation.

External Ankle Rotation

Ankle rotation causes the medial mortise to close on AP ankle projections. When an AP ankle demonstrates a closed medial mortise, one can determine which way the leg was rotated by evaluating the amount of tibia superimposition of the fibula and the alignment of the anterior and posterior

margins of the tibia that are adjacent to the medial malleolus (**Fig. 6.90**). In external rotation, the tibia superimposes more than one-half of the fibula, and the anterior tibial margin superimposes the talus, closing the medial mortise (**Fig. 6.91**).

TABLE 6.10

AP, Anteroposterior; *BOS*, base of support; *COG*, center of gravity; *CR*, central ray; *IR*, image receptor.

image

FIGURE 6.86 AP ankle projection with accurate positioning.

image

FIGURE 6.87 Proper patient positioning for AP ankle projection.

Internal Ankle Rotation

If an AP ankle is obtained with internal rotation, the resulting projection demonstrates the tibia superimposing less than one-half of the fibula, and the talus superimposing the posterior tibial margin, closing the medial mortise (**Fig. 6.92**).

FIGURE 6.88 Proper patient positioning for a weight-bearing bilateral AP ankle projection.

image

FIGURE 6.89 AP ankle projection of a patient with a ruptured ligament.

Weight-Bearing Bilateral AP Ankle: CR Off-Centering Versus Lateral Rotation

The CR is centered between the ankles for bilateral AP ankles. This off-centering of the CR results in laterally diverged x-rays recording the ankles and causing the resulting projection to appear as if the legs were in external

rotation for the projection, demonstrating a closed medial mortise and the tibia superimposing more than one-half of the fibula (**Fig. 6.93**). The farther apart the ankles are positioned from each other, the greater will be the amount of lateral divergence and the more laterally rotated the ankles will appear. This appearance can be offset by estimating the degree of x-ray divergence (2 degrees for every 1 inch off-center) and increasing the degree of internal rotation of the legs from the standard positioning by the same degree.

image

FIGURE 6.90 AP oblique (mortise) ankle projection taken with foot inverted and insufficient obliquity.

image

FIGURE 6.91 AP ankle projection taken with the ankle externally rotated.

image

FIGURE 6.92 AP ankle projection taken with the ankle internally rotated.

Openness of Tibiotalar Joint Space

On an AP ankle projection, determine whether an open joint was obtained and whether the tibia is demonstrated without foreshortening by evaluating the anterior and posterior margins of the distal tibia adjacent to the joint

space. On an AP ankle projection with accurate positioning, the anterior margin is demonstrated approximately 0.125 inch (3 mm) proximal to the posterior margin.

If the proximal lower leg is elevated for non–weight-bearing or brought farther from IR than the distal lower leg for the weight-bearing or the CR is centered proximally to the ankle joint for an AP ankle projection, the anterior tibial margin is projected distally, resulting in a narrowed tibiotalar joint space on the resulting projection (**Fig. 6.94**).

If the distal lower leg is elevated for a non–weight-bearing AP ankle, the anterior tibial margin is projected more proximally to the posterior margin than what is typically seen on an AP ankle projection, expanding the tibiotalar joint space and demonstrating the tibial articulating surface (**Fig. 6.95**).

FIGURE 6.93 Accurately positioned weight-bearing bilateral AP ankle projection.

FIGURE 6.94 AP ankle projection taken with the CR centered too proximally.

FIGURE 6.95 AP ankle projection taken with the distal lower leg elevated.

AP Ankle Analysis Practice

image

IMAGE 6.18

Analysis

The medial mortise is obscured, the tibia superimposes more than one-half of the fibula, and the anterior tibial margin is lateral to the posterior margin. The ankle was externally rotated.

Correction

Internally rotate the ankle.

image

IMAGE 6.19

Analysis

The tibia superimposes less than one-half of the fibula, the posterior tibial margin is lateral to the anterior margin and is superimposed by the talus, and the medial mortise is closed. The ankle was internally rotated.

Correction

Externally rotate the ankle.

Ankle: AP Oblique Projection (Medial Rotation)

See **Table 6.11** and Figs. **6.96–6.98**.

TABLE 6.11

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

image

FIGURE 6.96 AP (mortise) oblique ankle projection with accurate positioning.

image

FIGURE 6.97 AP (45-degree) oblique ankle projection with accurate positioning.

15- to 20-Degree AP Oblique (Mortise)

To obtain the proper degree of rotation for a mortise position, while viewing the plantar surface of the foot, place your index fingers on the most prominent aspects of the lateral and medial malleoli, and then internally rotate the leg until your index fingers and the malleoli are positioned at equal distances from the IR (**Fig. 6.99**). This positioning aligns the intermalleolar plane parallel with the IR, rotates the fibula away from the talus to demonstrate an open lateral mortise, and typically requires 15 to 20 degrees of obliquity.

image

FIGURE 6.98 Proper patient positioning for a 45-degree AP oblique ankle projection.

Mortise: Insufficient Internal Rotation

If the leg and ankle are internally rotated less than the needed degrees for an AP oblique ankle mortise projection, the tibia superimposes more than one-fourth of the fibula, and the lateral and medial mortises are closed (**Fig. 6.100**).

Mortise: Excessive Internal Rotation

If the ankle was internally rotated more than the needed degrees for an AP oblique ankle mortise projection, the tibia will superimpose less than one-fourth of the fibula and the lateral mortise will be open (**Fig. 6.101**).

FIGURE 6.99 Aligning the intermalleolar line parallel with the IR for AP oblique (mortise) ankle projection.

FIGURE 6.100 AP oblique (mortise) ankle projection taken with insufficient obliquity.

FIGURE 6.101 AP oblique (mortise) ankle projection taken with excessive obliquity.

image

FIGURE 6.102 AP oblique (mortise) ankle projection taken with foot inverted and insufficient obliquity.

image

FIGURE 6.103 AP (45-degree) oblique ankle projection taken with insufficient obliquity.

Foot and Ankle Inversion Versus Ankle Rotation

The leg and foot must stay aligned and rotated together for this projection. If the foot and ankle are inverted, without leg rotation, the ankle can appear to have been rotated when it has not, and the projection demonstrates a closed lateral mortise (**Fig. 6.102**).

45-Degree: Insufficient Internal Rotation

If the leg and ankle are internally rotated less than 45 degrees for a 45-degree AP oblique ankle, the tibia superimposes a part of the fibula, the lateral mortise is open unless the insufficiency is excessive, and the tarsal sinus is poorly demonstrated (**Fig. 6.103**).

45-Degree: Excessive Internal Rotation

If the leg and ankle are internally rotated more than 45 degrees for a 45-degree AP oblique ankle, the fibula superimposes a part of the tibia, the lateral mortise is closed, and the sinus tarsi will be clearly seen (**Fig. 6.104**).

Tibiotalar Joint Space Openness

- If the proximal lower leg was elevated or if the CR was centered proximal to the ankle joint, the anterior tibial margin is projected distally, resulting in a narrowed or obscured tibiotalar joint space. The more the lower leg is elevated or the greater the distance the CR is to the joint space, the greater will be the tibiotalar joint narrowing.
- If the distal lower leg was elevated, the anterior tibial margin is projected more proximally to the posterior margin, expanding the tibiotalar joint space and demonstrating the tibial articulating surface (**Figs. 6.105** and **6.106**). The greater the elevation the greater will be the joint space expansion.

image

FIGURE 6.104 AP (45-degree) oblique ankle projection obtained with excessive obliquity.

image

FIGURE 6.105 AP oblique (mortise) ankle projection taken with the distal lower leg elevated.

Foot Dorsiflexion

If the foot is not dorsiflexed for the AP oblique ankle, the distal aspects of the lateral mortise and distal fibula superimpose the calcaneus and obscure their visualization (**Figs. 6.107** and **6.108**).

image

FIGURE 6.106 AP (45-degree) oblique ankle projection taken with the distal lower leg elevated.

image

FIGURE 6.107 AP oblique (mortise) ankle projection taken without the foot dorsiflexed.

image

FIGURE 6.108 AP (45-degree) oblique ankle projection taken without the foot dorsiflexed.

AP Oblique Ankle Analysis Practice

image

IMAGE 6.20 AP oblique (mortise) projection.

Analysis

The medial mortise is closed, and there is no tibia superimposition of the fibula. The projection was obtained with more than 15 to 20 degrees of leg and ankle obliquity. The tibiotalar joint space is expanded, the anterior tibial margin has been projected proximal to the posterior margin, and the tibial articulating surface is demonstrated. The distal lower leg was elevated.

Correction

Externally rotate the leg and ankle until the medial and lateral malleoli are positioned at equal distances from the IR and depress the distal tibia or elevate the proximal lower leg and IR on a sponge until the lower leg is parallel with the IR.

image

IMAGE 6.21 AP oblique (45-degree) projection.

Analysis

The tibia is superimposing a small part of the fibula and the tibiofibular joint is closed. The calcaneus is obscuring the distal aspect of the lateral mortise and distal fibula. The leg and ankle were insufficiently internally rotated and the foot was in plantar flexion.

Correction

Internally rotate to 45 degrees and dorsiflex the foot until its long axis forms a 90-degree angle with the lower leg.

Ankle: Lateral Projection (Mediolateral)

See **Table 6.12** and **Figs. 6.109** and **6.110**.

Non–Weight-Bearing: Lower Leg and Foot Alignment

Foot plantar flexion results in a forced flattening of the anterior pretalar fat pad, reducing its usefulness in the detection of joint effusion. Dorsiflexing the foot to a 90-degree angle with the lower leg places the tibiotalar joint in a neutral position and tightens the ligament and muscle structures that will help to prevent foot and ankle rotation. To obtain a lateral ankle on a patient

who is unable to dorsiflex, the knee needs to be slightly flexed and an immobilization support placed beneath it to elevate it the needed amount to place the plantar surfaces of the heel and forefoot perpendicular with the IR (**Fig. 6.111**).

Weight-Bearing: Lower Leg and Foot Alignment

Weight-bearing lateral ankle projections are obtained to demonstrate how the ankles will react to having the patient's weight on them. The amount of the patient's weight that is placed on each foot and ankle is determined by placement of the COG in reference to the BOS, as described above in the AP and lateral foot projections (**Figs. 6.112** and **6.113**).

Non–Weight-Bearing: Elevated Proximal Lower Leg

If the lower leg is not placed parallel with the IR, by keeping the knee extended or by elevating the distal lower leg in a patient with a thick upper thigh, the proximal lower leg is positioned farther from the imaging table than the distal lower leg. The resulting projection demonstrates the lateral talar dome proximal to the medial dome, less than one-half (0.5 inch [1.25 cm]) of the cuboid is demonstrated posterior to the navicular bone if the patient has an average medial arch, the distal fibula is less than 0.25 inch (0.6 cm) distal to or is proximal to the distal tibia, and the talocalcaneal and tibiotalar joints are closed (**Fig. 6.114**).

Non–Weight-Bearing: Elevated Distal Lower Leg

If the distal lower leg is elevated higher than the proximal lower leg for a lateral ankle, the resulting projection demonstrates the lateral talar dome distal to the medial talar dome, more than one-half (0.5 inch [1.25 cm]) of the cuboid posterior to the navicular bone if the patient has an average medial arch, the distal fibula greater than 0.25 inch (0.6 cm) distally to the

distal medial tibia, an open talocalcaneal joint, and a closed tibiotalar joint (**Fig. 6.115**).

Weight-Bearing: Proximal Lower Leg Positioned Closer to the IR Than Distal Lower Leg

If the feet are positioned closer than hip width apart, the patient demonstrates a varus knee condition or the COG is shifted from the BOS center toward the affected ankle for a weight-bearing lateral ankle, the ankle will be everted, the proximal lower leg will be positioned closer to the IR than the distal lower leg, and the foot will be laterally rotated. The resulting projection will demonstrate the medial talar dome proximally to the lateral talar dome, more than one-half of the cuboid posteriorly to the navicular bone if the patient has an average medial arch, the distal fibula greater than 0.25 inch (0.6 cm) distally to the distal medial tibia, an open talocalcaneal joint, and a closed tibiotalar joint (**Fig. 6.116**).

Weight-Bearing: Proximal Lower Leg Positioned Farther Away From the IR Than Distal Lower Leg

If the feet are positioned farther than a hip width apart, the patient demonstrates a valgus knee condition, or the COG is shifted from the BOS center toward the unaffected foot for a weight-bearing lateral foot, the ankle will be inverted, the proximal lower leg positioned farther from the IR than the distal lower leg, and the foot medially rotated. The resulting projection will demonstrate the lateral talar dome proximally to the medial talar dome, less than one-half of the cuboid posteriorly to the navicular bone if the patient has an average medial arch, the distal fibula less than 0.25 inch (0.6 cm) distally to or the distal fibula proximally to the distal tibia, and closed talocalcaneal and tibiotalar joint spaces (**Fig. 6.117**).

TABLE 6.12

CR, Central ray; *IR*, image receptor; *MT*, metatarsal.

External Leg Rotation

If the leg is externally rotated more than needed to place the lateral foot surface parallel with the IR for a lateral ankle, the resulting projection demonstrates the medial talar dome anterior to the lateral talar dome and the anterior distal fibula aligned posteriorly to the mid-tibia (Figs. **6.61**, **6.118**, and **6.119**).

Internal Leg Rotation

If the leg is not externally rotated enough to place the lateral foot surface parallel with the IR for a lateral ankle projection, placing more surface pressure at the heel, the resulting projection demonstrates the medial talar dome posterior to the lateral talar dome and the anterior distal fibula aligned anteriorly to the mid-tibia (Figs. **6.63**, **6.120**, and **6.121**).

image

FIGURE 6.109 Lateral ankle projection with accurate positioning.

image

FIGURE 6.110 Properly positioned lateral ankle projection.

FIGURE 6.111 Lateral ankle projection taken without the foot dorsiflexed.

Weight-Bearing Lateromedial Projection

The lateromedial projection of the ankle should meet all the analysis guidelines listed for the mediolateral ankle projection. The most common misposition for standing lateromedial projections of the ankle is external rotation that is caused when the medial foot surface is positioned parallel with the IR rather than the lateral (see **Figs. 6.65** and **6.67**). This mispositioning is demonstrated on a weight-bearing lateromedial projection when the medial talar dome is positioned anterior to the lateral dome and the anterior fibula is aligned posterior to the mid-tibia (**Fig. 6.122**).

FIGURE 6.112 Weight-bearing mediolateral ankle projection with accurate positioning.

FIGURE 6.113 Weight-bearing mediolateral ankle projection taken with a foot and lower leg angle that is greater than 90 degrees. The COG was closer to the unaffected foot. The patient has a distal fibular fracture and should not have been placed in a weight-bearing position unless ordered by the physician.

image

FIGURE 6.114 Lateral ankle projection taken with the proximal lower leg elevated.

image

FIGURE 6.115 Lateral ankle projection taken with the distal lower leg elevated.

image

FIGURE 6.116 Weight-bearing mediolateral ankle projection taken with the proximal lower leg placed closer to the IR than the distal lower leg. Feet are closer than hip width apart.

image

FIGURE 6.117 Weight-bearing lateral ankle with the proximal lower leg positioned farther from the IR than the distal lower leg. Feet are positioned farther than a hip width apart.

image

FIGURE 6.118 Lateral ankle projection taken with the leg externally rotated.

image

FIGURE 6.119 Weight-bearing mediolateral ankle projection obtained with external rotation.

image

FIGURE 6.120 Weight-bearing mediolateral ankle projection taken with internal rotation.

image

FIGURE 6.121 Weight-bearing mediolateral ankle projection taken with the leg internally rotated.

image

FIGURE 6.122 Weight-bearing lateromedial ankle projection taken with the ankle in external rotation.

image

FIGURE 6.123 Lateral ankle projection demonstrating a Jones fracture.

Including the Fifth Metatarsal Base

An inversion injury of the foot and ankle may result in a fracture of the fifth MT base, known as a Jones fracture (**Fig. 6.123**). Including the fifth MT

base on the lateral ankle projection allows it to be evaluated for a Jones fracture, eliminating the need for additional projections.

Lateral Ankle Analysis Practice

image

IMAGE 6.22

Analysis

The lateral talar dome is proximal and anterior to the medial dome, less than one-half of the cuboid is demonstrated posterior to the navicular bone, the talocalcaneal and tibiotalar joint spaces are closed, and the anterior distal fibula is aligned anteriorly to the mid-tibia. The knee was flexed, elevating the proximal lower leg, and the lateral foot surface was not parallel with the IR. The leg was internally rotated. The foot was plantar flexed.

Correction

Extend the knee to position the lower leg parallel with the IR. If the knee was extended for this projection, elevate the lower leg until it is positioned parallel with the IR. Externally rotate the leg until the lateral foot surface is parallel with the IR. Dorsiflex the foot to a 90-degree angle with the IR.

image

IMAGE 6.23

Analysis

The medial talar dome is positioned anterior to the lateral talar dome, as indicated by the anterior distal fibula being aligned posterior to the mid-tibia. The leg was externally rotated. The foot has not been dorsiflexed to 90 degrees with the lower leg.

Correction

Dorsiflex the foot to 90 degrees with the lower leg and internally rotate the leg until the lateral foot surface is parallel with the IR.

image

IMAGE 6.24

Analysis

The lateral talar dome is positioned posteriorly and distally to the medial talar dome. The anterior distal fibula is aligned posterior to the mid-tibia, more than one-half of the cuboid is demonstrated posterior to the navicular, and the talocalcaneal joint is open. The leg was externally rotated and the distal lower leg was elevated higher than the proximal lower leg.

Correction

Internally rotate the foot until the lateral foot surface is parallel with the IR, and depress the distal lower leg until the lower leg is positioned parallel with the IR.

IMAGE 6.25 Weight-bearing mediolateral projection.

Analysis

The lateral talar dome is positioned anteriorly and proximally to the medial talar dome. The anterior distal fibula is aligned anteriorly to the mid-tibia. The leg was internally rotated and the proximal lower leg was elevated higher than the distal lower leg.

Correction

Externally rotate the foot until the lateral foot surface is parallel with the IR and depress the proximal lower leg until the lower leg is positioned parallel with the IR.

Lower Leg: AP Projection

See **Table 6.13** and **Figs. 6.124** and **6.125**.

Anatomical Position Versus AP Projections of the Ankle and Knee

To place the patient in anatomic position, the legs are internally rotated until the femoral epicondyles are aligned parallel with the IR, placing the knees in an AP projection and the ankles in a 15- to 20-degree internal AP (mortise) oblique. In this position, the tibia will superimpose about one-half of the fibular head (as is expected on an AP knee) and one-fourth of the distal fibula (as is expected on a mortise ankle). This is contrary to the AP ankle projection discussed previously, as the leg and foot were not internally rotated for the projection, but remained vertical, and the resulting projection demonstrates the tibia superimposing about one-half of the distal

fibula. If the lower leg were taken with the ankle in an AP projection, the knee would not be in an AP projection but in a slight externally rotated position and would demonstrate the tibia superimposing more than 0.5 inch (1.25 cm) of the fibular head (**Fig. 6.126**). Because the ankle and knee joints cannot be demonstrated in a true AP projection at the same time, the image analysis guidelines and positioning procedures listed in **Table 6.13** are for a projection in which the knee and ankle are placed in slight oblique positions, halfway between the AP knee and AP ankle.

Positioning for Fracture

For a patient with a known or suspected lower leg fracture, position the joint closest to the fracture in a true AP ankle or AP knee projection, as described earlier in this chapter. If the fracture is situated closer to the distal lower leg, the ankle is positioned with the foot vertical and the knee is in slight external rotation. The resulting projection demonstrates the tibia superimposing about one-half of the distal fibula. The amount of proximal tibia and fibular superimposition will depend on the fracture's effect on leg rotation (**Fig. 6.127**). If the fracture is situated closer to the proximal lower leg, the knee is positioned with the femoral epicondyles parallel with the IR and the lower leg is in slight internal rotation. The resulting projection demonstrates the tibia superimposing about one-half of the fibular head. The amount of distal tibia and fibular superimposition will depend on the fracture's effect on leg rotation.

TABLE 6.13

CR, Central ray; *IR*, image receptor.

FIGURE 6.124 AP lower leg projection with accurate positioning.

FIGURE 6.125 Proper patient positioning for AP lower leg projection.

FIGURE 6.126 AP lower leg projection taken with the ankle in an AP projection and the knee and slight external rotation.

External Leg Rotation

Rotation of the lower leg can be identified on an AP projection by evaluating the relationship of the fibula to the tibia. When the lower leg is too externally rotated, the tibia superimposes more than one-fourth of the fibular head and more than one-half of the distal fibula. Increased external rotation will also cause the tibia to superimpose the fibular midshaft (**Fig. 6.128**).

Internal Leg Rotation

If the leg is too internally rotated, the tibia superimposes less than one-fourth of the fibular head and less than one-half of the distal fibula (**Fig. 6.129**).

Knee and Ankle Joint Spaces

When the lower leg is placed parallel with the IR and the CR is centered to the midshaft of the lower leg, the x-rays that record the knee joint space are diverging in the opposite direction of the tibial plateau, which slopes distally from the anterior to the posterior margins, causing the knee joint to be closed on AP lower leg projections (**Fig. 6.130**). The articulating surface of the distal tibia also slopes distally from the anterior to the posterior margin by approximately 3 degrees. Although the x-rays diverge in the same direction as this slope, they diverge at a greater angle, which causes the ankle joint to be closed.

FIGURE 6.127 AP lower leg projection of a patient with a distal lower leg fracture.

FIGURE 6.128 AP lower leg projection taken with the leg externally rotated.

FIGURE 6.129 AP lower leg projection taken with the leg internally rotated.

image

FIGURE 6.130 Effect of x-ray divergence on AP lower leg projection.

AP Lower Leg Analysis Practice

image

IMAGE 6.26

Analysis

The distal lower leg has been clipped, and the distal and proximal fibula is free of tibial superimposition. The CR and IR were positioned too proximally and the leg was internally rotated.

Correction

Move the CR and IR 1 inch (2.5 cm) distally and externally rotate the leg to an AP projection.

Lower Leg: Lateral Projection (Mediolateral)

See **Table 6.14** and Figs. **6.131**–**6.133**.

Variation From the True Lateral Knee and Ankle Projections

Because the ankle and knee joints cannot be demonstrated in lateral projections at the same time as explained in the AP lower leg projection (see **Fig. 6.126**), the image analysis guidelines and positioning procedures listed in **Table 6.14** are for a projection that is in slight internal rotation

from the true lateral knee and slight external rotation from the true lateral ankle.

Positioning for Fracture

For a patient with a known or suspected lower leg fracture, position the joint closest to the fracture in a lateral ankle or lateral knee projection as described earlier in this chapter. If the fracture is situated closer to the distal lower leg, the ankle is positioned with the lateral surface of foot aligned parallel with IR and the resulting projection will demonstrate the fibula superimposed by the posterior one-half of the tibia. The amount of proximal tibia and fibula superimposition will depend on the fracture's effect on leg rotation (**Fig. 6.134**). If the fracture is situated closer to the proximal lower leg, the knee is positioned with the femoral epicondyles positioned perpendicular with the IR and the resulting projection will demonstrate the tibia superimposing about one-half of the fibular head. The amount of distal tibia and fibular superimposition will depend on the fracture's effect on leg rotation.

TABLE 6.14

CR, Central ray; *IR*, image receptor.

image

FIGURE 6.131 Lateral lower leg projection with accurate positioning.

External Leg Rotation

Superimposition of the femoral condyles and the talar domes are good indicators of rotation on lateral knee and ankle projections, but are not reliable for the lateral lower leg, as neither the knee nor the ankle is placed in a true lateral projection. The amount of femoral condyle superimposition also depends on the degree of knee flexion and the way in which the diverged x-ray beams were aligned with the medial condyle (see the discussion on lateral knee projection). Rotation is then best distinguished on a lateral lower leg projection by viewing the degree of tibia and fibular head superimposition. If the leg was too externally rotated, the tibia superimposes less than one-half of the fibular head (**Fig. 6.135**).

image

FIGURE 6.132 Pediatric lateral lower leg projection with accurate positioning.

Internal Leg Rotation

If the leg was too internally rotated, the tibia superimposes more than one-half of the fibular head, the tibial and fibular midshafts demonstrate some degree of superimposition, and the posterior aspect of the distal fibula will be slightly anterior to the posterior aspect of the distal tibia (**Fig. 6.136**).

image

FIGURE 6.133 Proper patient positioning for lateral lower leg projection.

image

FIGURE 6.134 Lateral lower leg projection of a patient with a distal lower leg fracture.

image

FIGURE 6.135 Lateral lower leg projection taken with excessive external rotation.

image

FIGURE 6.136 Lateral lower leg projection taken with insufficient external rotation.

Lateral Lower Leg Analysis Practice

image

IMAGE 6.27

Analysis

The tibia superimposes more than one-half of the fibular head, and the entire fibular midshaft, and the posterior aspect of the distal fibula is anterior to the posterior aspect of the distal tibia. The leg was internally rotated.

Correction

Externally rotate the leg until it is in a lateral projection.

image

IMAGE 6.28

Analysis

The tibia is superimposing less than one-half of the fibular head. The leg was externally rotated more than needed to position it in a lateral projection.

Correction

Internally rotate the leg to a lateral projection.

Knee: AP Projection

See **Table 6.15** and Figs. **6.137**–**6.140**.

Total Knee Replacement

Preoperative and postoperative total knee replacement (TKR) AP knee projections are best taken in the standing, weight-bearing position. Preoperative TKR projections are obtained to demonstrate bony abnormalities, joint space narrowing, and the degree of valgus or varus deformity. A radiopaque templating marker is placed in the exposure field to be used to determine the magnification factor, which is then used by surgeons to determine the size of the implant that is needed and to anticipate problems that might arise due to abnormalities of mechanical alignment and bone structures (**Fig. 6.141**). Postoperative TKR projections are obtained to evaluate the prosthesis fit and wear, degree of valgus or varus deformity, and joint space loss.

Internal Leg Rotation

If the leg was internally rotated more than needed to bring the epicondyles parallel with the IR for an AP knee, the medial epicondyle will be closer to the IR than the lateral, and the resulting projection will demonstrate a larger appearing lateral femoral condyle when compared with medial femoral condyle, and the tibia superimposing over less than one-half of the fibular head (**Fig. 6.142**). For TKR projections, rotation of the femoral component makes it difficult to determine the direction of the rotation by viewing the femoral condyles. When the femoral condyles and TKR components are not symmetrical, the tibia and fibular relationship is best used to indicate the direction the knee was rotated (**Fig. 6.143**).

image

FIGURE 6.137 AP knee projection with accurate positioning.

image

FIGURE 6.138 Accurately positioned standing bilateral AP knees with templating magnification marker.

image

FIGURE 6.139 Proper patient positioning for AP lateral knee projection.

image

FIGURE 6.140 Accurately positioned weight-bearing AP knee projection.

TABLE 6.15

AP, Anteroposterior; *BOS*, base of support; *COG*, center of gravity; *CR*, central ray; *IR*, image receptor.

External Leg Rotation

If the leg is not internally rotated enough to place the epicondyles parallel with the IR for an AP knee, the lateral epicondyle is placed closer to the IR than the medial, and the resulting projection will demonstrate a larger appearing medial femoral condyle when compared with the lateral and the tibia superimposing more than one-half of the fibular head (**Figs. 6.144** and **6.145**).

Weight-Bearing Bilateral AP Knees: CR Off-Centering Versus External Rotation

For bilateral AP knee projections the CR is centered between the knees. This off-centering of the CR results in laterally diverged x-rays recording the knees and causing the resulting projection to appear as if the legs were in external rotation for the projection, demonstrating a larger appearing medial femoral condyle when compared with the lateral, and the tibia superimposing more than one-half of the fibular head (**Fig. 6.146**). The farther apart the knees are positioned from each other, the greater will be the amount of lateral divergence and the more laterally rotated the knees will appear. This appearance can be offset by estimating the degree of x-ray

divergence (2 degrees for every 1 inch of off-center) and increasing the degree of internal rotation of the legs from the standard positioning by the same degree.

Femoral Tilt With the IR: Intercondylar Fossa Visualization

As the knee is flexed, the distal femur moves away from the IR, increasing the tilt between the long axis of the femur and IR. As this tilt increases, the amount of the intercondylar fossa that is demonstrated increases and the placement of the patella in relationship to the intercondylar fossa changes. **Fig. 6.147** demonstrates a series of AP flexed knee projections taken with different degrees of knee flexion and femoral tilt with the IR. Note that when the knee is in full extension, only a slight upward curve between the medial and lateral femoral condyles indicates the location of the intercondylar fossa. As the degree of knee flexion and femoral tilt with the IR increases, the degree of intercondylar fossa visualization also increases until it is in full visualization around 60 to 70 degrees, after which increased femoral tilt with the IR will cause a decrease in its visualization again. Increased knee flexion and femoral tilt causes the patella to move from its initial slight lateral position in full extension, distally and medially onto the patellar surface of the femur, and then laterally onto the intercondylar fossa, duplicating a C-shaped path that is open laterally (**Fig. 6.148**). The location of the patella in reference to the intercondylar fossa can be used as an indicator of the degree of knee flexion that was present when the projection was obtained. Projections demonstrating the patellar apex proximal to the intercondylar fossa are flexed less than those demonstrating the patellar apex in the fossa. It takes about 70 degrees of femoral tilt with the IR to see the patellar apex in the fossa.

Patellar Subluxation

With patellar subluxation (partial patellar dislocation), the patella may be situated more laterally than normal on an extended AP knee projection (**Fig. 6.149**). When an AP knee projection demonstrates a laterally situated patella, evaluate it for external rotation, as this also causes the patella to be demonstrated laterally.

FIGURE 6.141 AP weight-bearing projection of pre- and postoperative TKR.

FIGURE 6.142 AP knee projection taken with excessive internal rotation.

FIGURE 6.143 AP knee projection with TKR taken with internal rotation.

FIGURE 6.144 AP knee projection taken with external rotation.

image

FIGURE 6.145 AP knee projection with TKR taken with external rotation.

image

FIGURE 6.146 Weight-bearing, bilateral AP knee projection obtained without increased internal leg rotation to offset lateral beam divergence.

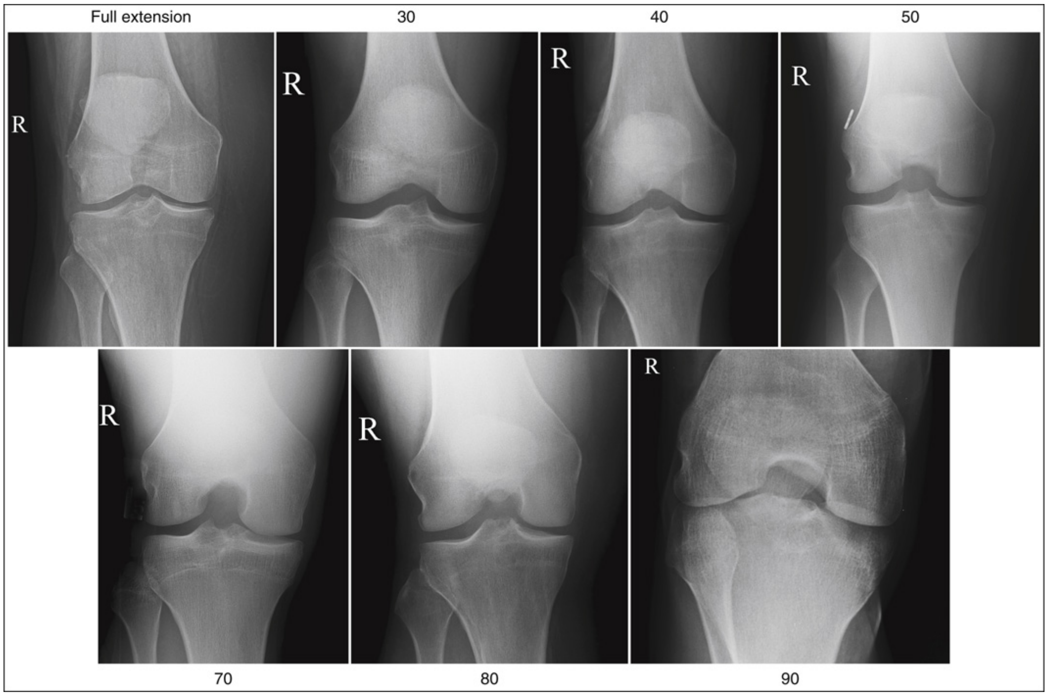


FIGURE 6.147 Series of AP flexed knee projections taken with different degrees of knee flexion and femoral tilt with the IR to show how the amount of the intercondylar fossa demonstrated increases and the placement of the patella in relationship to the intercondylar fossa changes with increased flexion.

image

FIGURE 6.148 Movement of patella on knee flexion.

CR and Tibial Plateau Alignment

To obtain an open knee joint space and optimal demonstration of the intercondylar eminence and tubercles without foreshortening on an AP knee(s) projection the CR must be aligned parallel with the tibial plateau.

When the lower leg is positioned parallel with the IR, the tibial plateau slopes distally approximately 3 to 5 degrees from the tibia's anterior condylar margin to its posterior condylar margin on both the medial and lateral aspects and would require a 5-degree caudal CR angulation to obtain an open joint (**Fig. 6.150**). The degree and direction that the tibial plateau is with the IR and the needed CR angulation that is required to obtain an open knee joint is dependent on how tilted the lower leg is with the IR when positioned.

Non–Weight-Bearing: CR Alignment With Tibial Plateau

In a supine position, it is the thickness of the upper thigh and buttocks that determine how the lower leg and the tibial plateau will be aligned with the IR. **Fig. 6.151** shows a guideline that can be used to determine the CR angulation for different body sizes; it illustrates the relationship of the tibial plateau to the IR as the upper thigh thickness increases. Note that an increase occurs in femoral decline, and a shift occurs in the direction of the tibial plateau slope as the thickness of the thigh increases. Because of this plateau shift, the CR angulation must also be adjusted to keep it parallel with the plateau and to achieve an open knee joint. One method to determine the needed CR angulation is to measure from the anterior superior iliac spine (ASIS) to the imaging table on either side to determine the CR angulation to use for each knee examination as indicated on the illustration. When measuring this distance, do not include the abdominal tissue. Keep the calipers situated laterally next to the ASIS.

image

FIGURE 6.149 AP knee projection of patient with patellar subluxation.

image

FIGURE 6.150 Illustration to demonstrate the slope of the proximal tibia.

image

FIGURE 6.151 Determining the angle needed to align the CR parallel with the tibial plateau for the non–weight-bearing AP knee projection.

Weight-Bearing AP Knee(s): CR Alignment With the Tibial Plateau

In the weight-bearing position, even though the knees may appear fully extended they tend to remain in slight flexion because of the lack of the gravitational pull on the knee(s) and the decrease in flexibility that accompanies aging. This causes the proximal lower leg to be tilted slightly forward, commonly aligning the tibial plateau perpendicular to the IR and requiring the CR to be perpendicular to obtain an open knee joint space.

Flexed Knee Positioning to Obtain Open Knee Joint

To obtain an open knee joint space on an AP or AP oblique knee(s) projection regardless of the degree of knee flexion and lower leg tilt with the IR:

image

FIGURE 6.152 An open knee joint space is obtained on AP or AP oblique knee projections by aligning the CR with the tibial plateau.

1. Align the CR perpendicular to the long axis of the lower leg, and then
2. Decrease the angulation 5 degrees to align the CR parallel with the tibial plateau. For example, if the CR is perpendicular to the lower leg when a 15-degree cephalic angulation is used, the angle should be decreased to 10 degrees (**Fig. 6.152**).

Projections produced using this method will demonstrate an open joint space and some degree of the intercondylar fossa as described in **Fig. 6.147**, with the amount increasing as the degree of femoral tilt with the IR increases with increased knee flexion.

Closed Knee Joint: Excessive Cephalic Angulation

Determine how to adjust for poor CR angulation by judging the shape of the fibular head and its proximity to the tibial plateau. If the fibular head is foreshortened and is demonstrated at a distance that is more than 0.5 inch (1.25 cm) distal to the tibial plateau on an AP knee projection, the CR was angled too cephalically (**Fig. 6.153**).

image

FIGURE 6.153 AP knee projection taken with an excessive cephalic CR angulation.

Closed Knee Joint: Insufficient Cephalic Angulation

If the fibular head is elongated and is demonstrated at a distance that is less than 0.5 inch (1.25 cm) distal to the tibial plateau on an AP knee projection, the CR was angled too caudally (**Fig. 6.154**).

Valgus and Varus Deformities: Joint Space Narrowingz

On an AP knee with adequate positioning, joint space narrowing is evaluated by measuring the medial and lateral aspects of the knee joint. The measurement of each of these compartments is obtained by determining the distance between the most distal femoral condylar surface and the posterior condylar margin of the tibia on each side. Comparison of these measurements with each other, with measurements from previous projections, or with measurements of the other knee determines joint space narrowing or a valgus or varus deformity. In a valgus deformity, the lateral compartment is narrower than the medial compartment; in a varus deformity, the medial compartment is narrower (**Figs. 6.155** and **6.156**). Precise measurements of the compartments are necessary to ensure early detection of joint space narrowing and are best obtained when the knee joint space is completely open. If an inaccurate CR angulation was used for an AP knee, the knee joint is narrowed or obscured, the intercondylar eminence and tubercles are foreshortened, and the tibial plateau is demonstrated.

image

FIGURE 6.154 AP knee projection taken with inadequate cephalic CR angulation.

image

FIGURE 6.155 AP knee projection of a patient with valgus deformity.

Dislocated Knee

Although the dislocated AP knee projection will not demonstrate the femoral condyles and the tibial plateau in alignment, the goal is to obtain a projection that as closely as possible fulfills the analysis guidelines as listed in **Table 6.15** (**Fig. 6.157**).

image

FIGURE 6.156 AP knee projection of a patient with varus deformity.

image

FIGURE 6.157 AP knee projection demonstrating dislocation.

AP Knee Analysis Practice

image

IMAGE 6.29

Analysis

The medial side of the knee joint space is closed. The fibular head is foreshortened and is demonstrated more than 0.5 inch (1.25 cm) distal to the tibial plateau. The CR was angled too cephalically.

Correction

Adjust the CR angle caudally.

image

IMAGE 6.30

Analysis

The femoral epicondyles are not in profile, the medial femoral condyle appears larger than the lateral condyle, and the tibia superimposes more than one-half of the fibular head. The leg was externally rotated.

Correction

Internally rotate the leg until the femoral epicondyles are positioned parallel with the IR.

Knee: AP Oblique Projection (Medial and Lateral Rotation)

See **Table 6.16** and Figs. **6.158**–**6.161**.

Medial Oblique: Insufficient Internal Rotation

If the femoral epicondyles are rotated less than the required 45 degrees with the IR for the medial AP oblique knee, the resulting projection demonstrates the tibia partially superimposed over the fibular head (**Fig. 6.162**).

Medial Oblique: Excessive Internal Rotation

If the femoral epicondyles are rotated more than the required 45 degrees with the IR for the medial AP oblique knee, the resulting projection demonstrates excessive femoral condyle superimposition (**Fig. 6.163**).

Lateral Oblique: Insufficient External Rotation

If the femoral epicondyles are rotated less than the required 45 degrees with the IR for the lateral AP oblique knee, the fibular head is demonstrated without full tibial superimposition (**Fig. 6.164**).

Lateral Oblique: Excessive External Rotation

If the femoral epicondyles are rotated more than the required 45 degrees with the IR for a lateral AP oblique knee, the fibular head is not aligned with the anterior edge of the tibia but is seen posterior to this placement. The more posteriorly the fibula is situated, the farther away from 45 degrees the patient is positioned (**Fig. 6.165**).

Femoral Tilt With the IR: Intercondylar Fossa Visualization

The amount of the proximal intercondylar fossa that will be demonstrated when the femur is tilted with the IR is the same for the AP oblique knee projection as described above for the AP knee projection (see **Fig. 6.147**). As the tilt of the femur with the IR increases because of knee flexion, there is an increase in the amount of the proximal intercondylar fossa that is demonstrated up to 60 to 70 degrees when the full fossa is visualized. Because the knee is rotated, for the AP oblique projections the medial and lateral margins of the intercondylar fossa will not be superimposed (**Fig. 6.166**).

CR Alignment With Tibial Plateau

To obtain an open knee joint space on AP oblique knee projections when the patient is non–weight-bearing, the thickness of the upper thigh will affect the tibial plateau's alignment with the IR in the same way as discussed in **Fig. 6.151**. It is not uncommon to require a cephalic angle for the AP medial oblique when a perpendicular or caudal angle was used for the AP projection. This is because the hip is often elevated to accomplish the needed degree of internal obliquity, adding to the distance and slope. A caudal CR angle is often needed for the AP lateral oblique, because the pelvis is rotated toward the imaging table to accomplish the external oblique knee and the buttocks do not lift the proximal leg as high off the imaging table.

image

FIGURE 6.158 AP medial oblique knee projection with accurate positioning.

image

FIGURE 6.159 AP lateral oblique knee projection with accurate positioning.

image

FIGURE 6.160 Proper patient positioning for AP medial oblique knee projection.

image

FIGURE 6.161 Proper patient positioning for AP lateral oblique knee projection. *X* indicates medial femoral epicondyle.

image

FIGURE 6.162 AP medial oblique knee projection taken with insufficient internal rotation.

image

FIGURE 6.163 AP medial oblique knee projection taken with excessive internal rotation.

image

FIGURE 6.164 AP lateral oblique knee projection taken with insufficient external rotation.

image

FIGURE 6.165 AP lateral oblique knee projection taken with excessive external rotation.

TABLE 6.16

CR, Central ray; *IR*, image receptor.

Excessive CR Angulation

If the CR is angled too cephalically for AP oblique knees, the fibular head is foreshortened and is demonstrated more than 0.5 inch (1.25 cm) distal to the tibial plateau (**Fig. 6.167**).

Insufficient CR Angulation

If the CR is angled too caudally for AP oblique knees, the fibular head is elongated and demonstrated less than 0.5 inch (1.25 cm) distal to the tibial plateau (**Fig. 6.168**).

FIGURE 6.166 AP medial oblique knee projection obtained with the knee flexed 60 to 70 degrees.

FIGURE 6.167 AP medial oblique knee projection taken with excessive cephalic CR angulation.

image

FIGURE 6.168 AP medial oblique knee projection taken with inadequate cephalic CR angulation and with insufficient internal rotation.

AP Oblique Knee Analysis Practice

image

IMAGE 6.31 AP (lateral) oblique projection.

Analysis

The tibia is demonstrated without full tibia superimposition. The leg was externally rotated less than the required 45 degrees with the IR. The knee joint space is obscured, and the fibular head is foreshortened and demonstrated less than 0.5 inch (1.25 cm) distal to the tibial plateau. The CR was angled too caudally.

Correction

Increase the degree of external leg rotation until the femoral epicondyles are at a 45-degree angle with the IR and cephalically angle the CR.

image

IMAGE 6.32 AP (medial) oblique projection.

Analysis

The tibia superimposes a portion of the fibular head. The leg was internally rotated less than the required 45 degrees with the IR.

Correction

Increase the degree of internal leg rotation until the femoral epicondyles are at a 45-degree angle with the IR.

Knee: Lateral Projection (Mediolateral)

See **Table 6.17** and Figs. **6.169**–**6.171**.

Knee Flexion and Joint Effusion Visualization

Two soft tissue structures of interest at the knee are used to diagnose joint effusion and knee injury. They are the posterior and anterior suprapatellar fat pads. Both are located anterior to the patellar surface of the distal femur and are separated by the suprapatellar bursa (**Fig. 6.172**). Fluid that collects in the suprapatellar bursa causes the anterior and posterior suprapatellar fat pads to separate. It is a widening of this space that indicates a diagnosis of joint effusion (**Fig. 6.173**).

To best demonstrate the degree of fluid in the bursa on a lateral knee projection, knee flexion is best kept under 20 degrees. With this degree of flexion, the patella is situated proximal to the patellar surface of the femur, the quadriceps are relaxed, and the patella is fairly mobile, all allowing the anterior and posterior suprapatellar fat pads to be visible and useful in evaluating even small amounts of knee joint effusion. Conversely, when the knee is flexed more than 20 degrees, a tightening of the surrounding knee muscles and tendons is present, the patella comes into contact with the patellar surface of the femur, and the anterior and posterior suprapatellar fat pads are obscured, eliminating their usefulness in diagnosing joint effusion (**Fig. 6.174**).

Positioning for Fracture

If a patellar or other knee fracture is suspected, the knee should remain extended to prevent displacement of bony fragments or vascular injury (**Fig. 6.175**).

Total Knee Replacement

Postoperative TKR lateral knee projections are obtained to evaluate the sagittal alignment of the femoral and tibial components, cement integrity, and evaluate how ideally the components duplicate the patient's anatomy (**Fig. 6.176**).

CR Alignment: Open Knee Joint Space

When a patient is in an erect position with the legs separated so the knees are situated below the hip joints, the distal margins of the femoral epicondyles are aligned parallel with the floor and the femoral shafts incline medially up to 10 degrees (**Fig. 6.177**). This femoral incline aids balance and stability in the upright position. The amount of femoral inclination a person displays increases with increased pelvic width and decreased femoral shaft length (**Fig. 6.178**).

When patients are placed in the recumbent position and then rolled onto their side for a lateral knee projection, some of this medial femoral inclination is reduced, causing the medial femoral condyle to be positioned distal to the lateral condyle (**Fig. 6.179**). A lateral knee projection is obtained with a perpendicular CR, and this positioning will demonstrate the medial condyle distal to the lateral condyle and within the knee joint space, and the fibular head positioned less than 0.5 inch (1.25 cm) from the tibial plateau. The amount of distance demonstrated between the distal margins of the two femoral condyles and the fibular head and tibial plateau depends on the amount of the femoral incline there is to reduce. To project the medial condyle proximally, aligning the distal margins of the condyles, and opening the knee joint space on a recumbent lateral knee, the CR is angled cephalically 5 to 7 degrees.

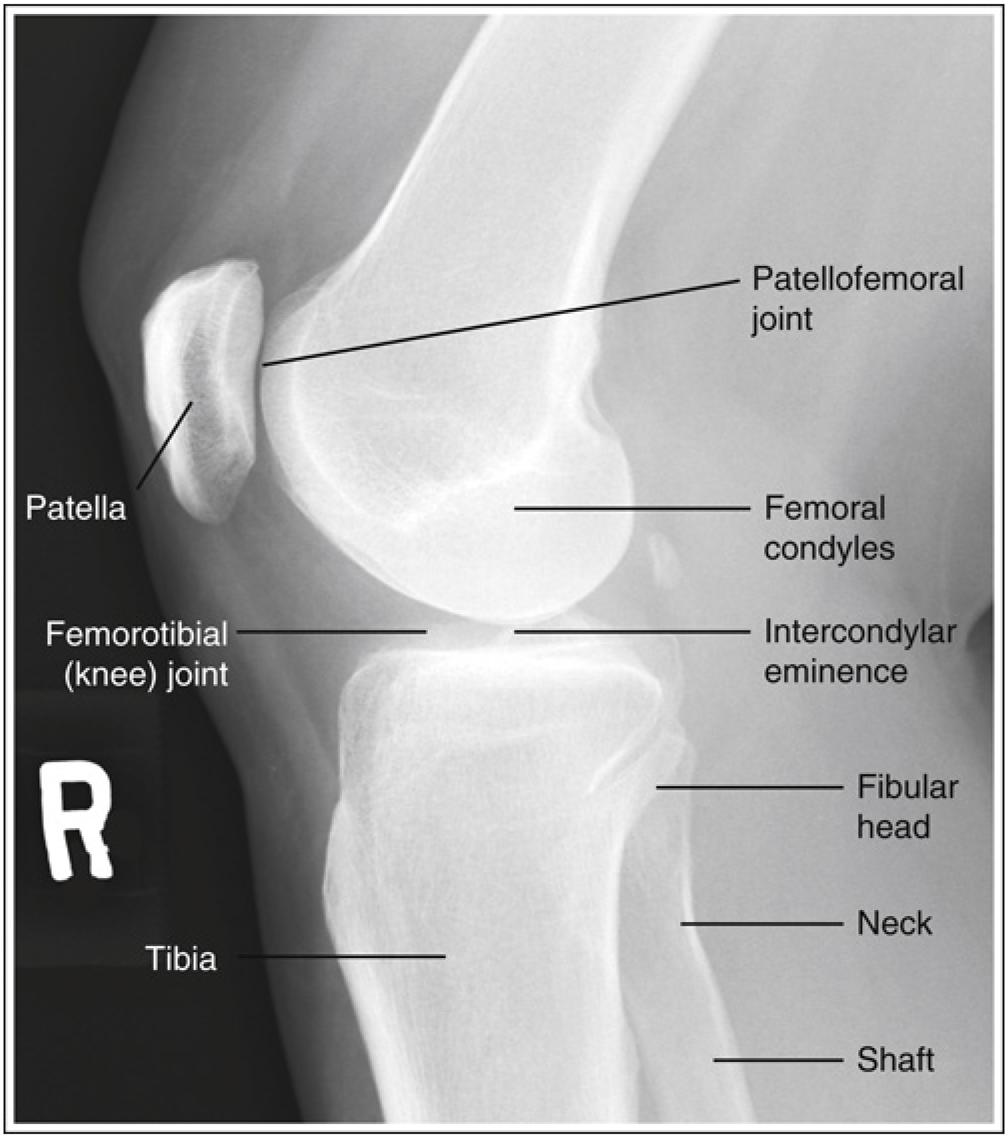


FIGURE 6.169 Lateral (mediolateral) knee projection with accurate positioning.

FIGURE 6.170 Pediatric lateral knee projection with accurate positioning.

FIGURE 6.171 Proper patient positioning for lateral knee projection. *X* indicates medial femoral epicondyle.

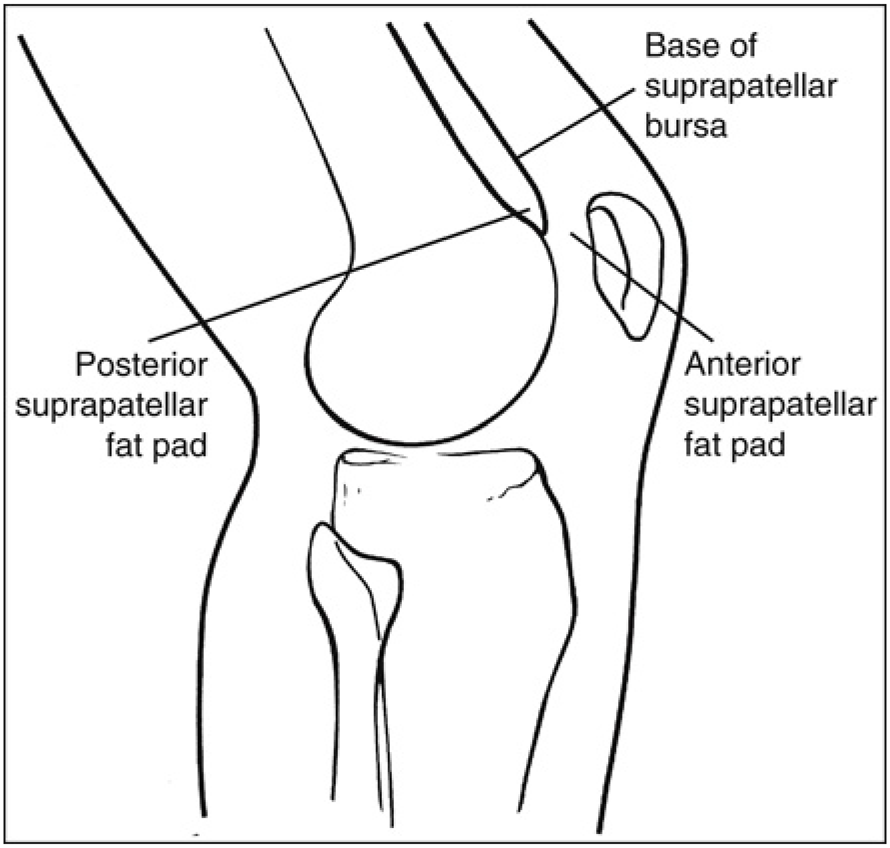


FIGURE 6.172 Location of suprapatellar fat pads.

TABLE 6.17

CR, Central ray; *IR*, image receptor.

Determining Degree of CR Angulation

Because the degree of femoral inclination varies among patients, so must the degree of needed CR angulation for the recumbent lateral knee projection. **Fig. 6.178** demonstrates bilateral long leg projections on three different patients in anatomical position. Note that the variation in the pelvis

width and femoral length caused different degrees of femoral inclination between the patients, with the wider pelvis and shorter femoral length resulting in the greatest femoral inclination. As femoral inclination increases, the distance between the distal femoral condyles will also increase in the recumbent lateral position, requiring an increase in the degree of cephalic CR angulation needed to project the medial condyle proximally enough to obtain an open joint space on the resulting lateral knee projection.

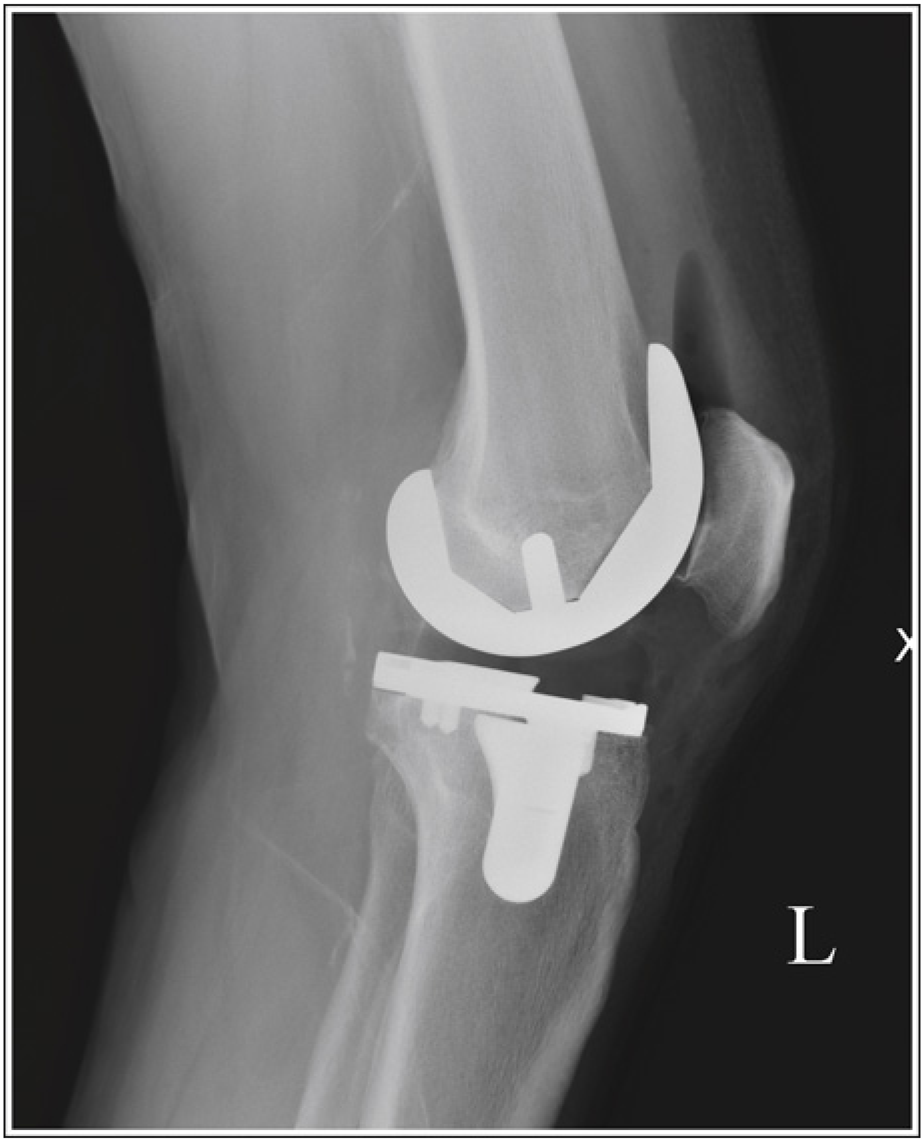


FIGURE 6.173 Lateral knee projection demonstrating joint effusion.

Although females commonly demonstrate greater pelvic width and femoral inclination and males demonstrate narrower pelvic width and femoral inclination, variations occur in both genders. Each patient's pelvic width and femoral length should be observed and assessed to determine the best degree of CR angulation to use before having the patient lie on the imaging table.

Distinguishing Lateral and Medial Condyles

The first step to take when evaluating a poorly positioned lateral knee is to distinguish the lateral and medial condyles. The most reliable method for identifying the medial condyle is to locate the rounded bony tubercle known as the adductor tubercle (**Fig. 6.180**). It is located posteriorly on the medial aspect of the femur, just superior to the medial condyle. The size and shape of the tubercle are not identical on every patient, although this margin is considerably different from the same margin on the lateral condyle, which is smooth. Once the adductor tubercle is located, the medial condyle is also identified. Another difference between the medial and lateral condyles is evident on their distal articulating surfaces. The distal margin of the medial condyle is convex, and the distal margin of the lateral condyle is flat.

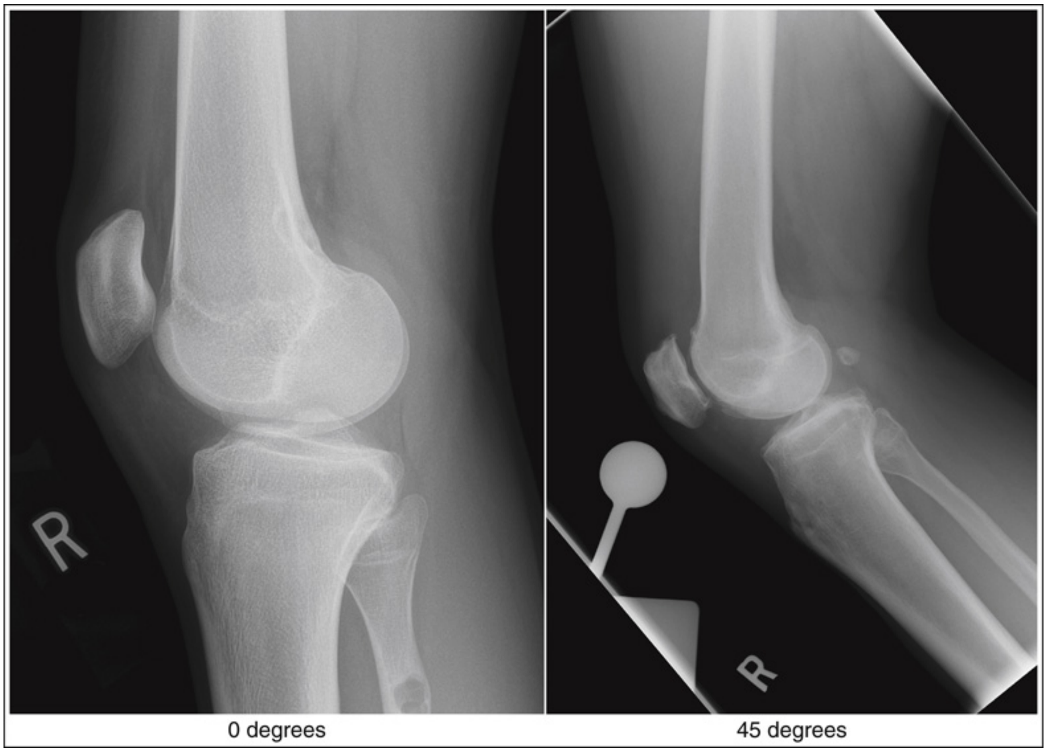


FIGURE 6.174 Extended and 45-degree flexed lateral knee projections.

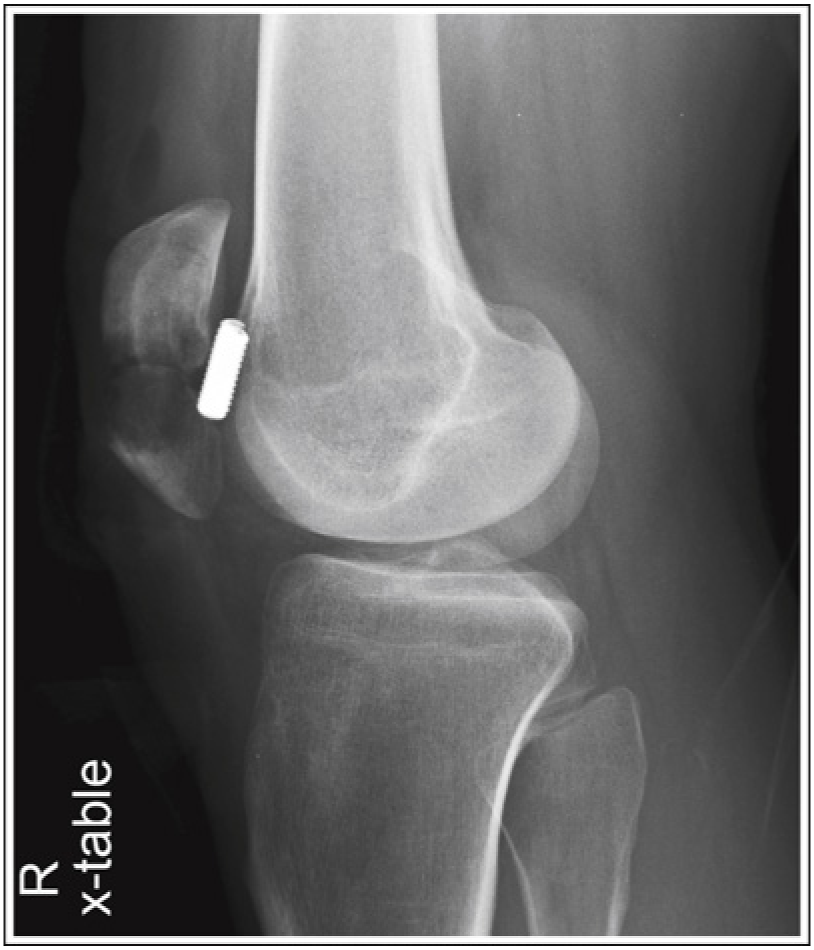


FIGURE 6.175 Crosstable lateral knee projection with fractured patella.

Insufficient CR Angulation: Medial Condyle in Joint Space

If a patient required a cephalic angulation to project the medial condyle proximally, but no angle was used, the resulting projection demonstrates the distal margin of the medial condyle distal to the distal margin of the lateral condyle, a narrowed or closed knee joint space, and less than 0.5 inch (1.25 cm) of distance between the fibular head and tibial plateau (**Fig. 6.181**).

Excessive CR Angulation: Lateral Condyle in Joint Space

If a patient did not require a cephalic angulation but one was used, or if the angle was too great, the distal margin of the medial condyle is projected proximal to the distal margin of the lateral condyle, narrowing or closing the knee joint space, and more than 0.5 inch (1.25 cm) of distance is demonstrated between the fibular head and the tibial plateau (**Fig. 6.182**).

Total Knee Replacement: Medial Femoral Condyle in Joint Space

When an inaccurate cephalic CR angulation is used for a TKR lateral knee projection the medial and lateral femoral pegs and femoral component are not aligned proximally or distally. A TKR lateral knee obtained with insufficient cephalic CR angulation demonstrates the medial femoral component in the knee joint space, causing it to be narrowed or closed knee joint space, and the fibular head extending to the proximal aspect of the plastic tibial tray (**Fig. 6.183**).

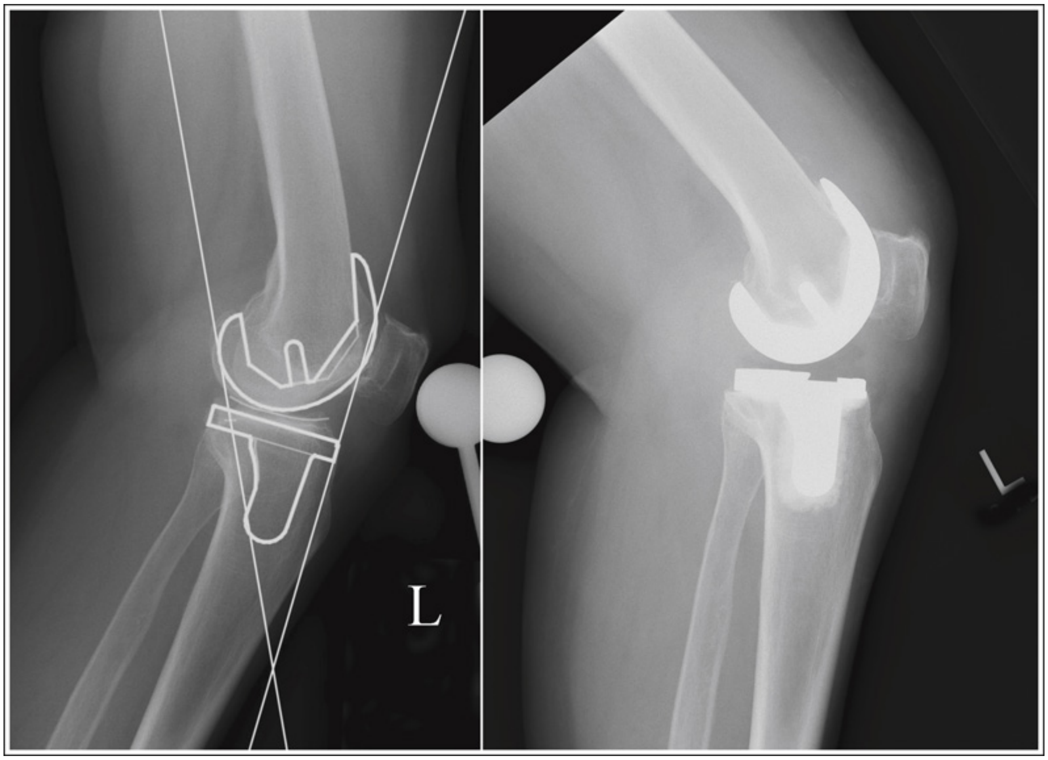


FIGURE 6.176 Lateral knee projection of pre- and postoperative TKR.

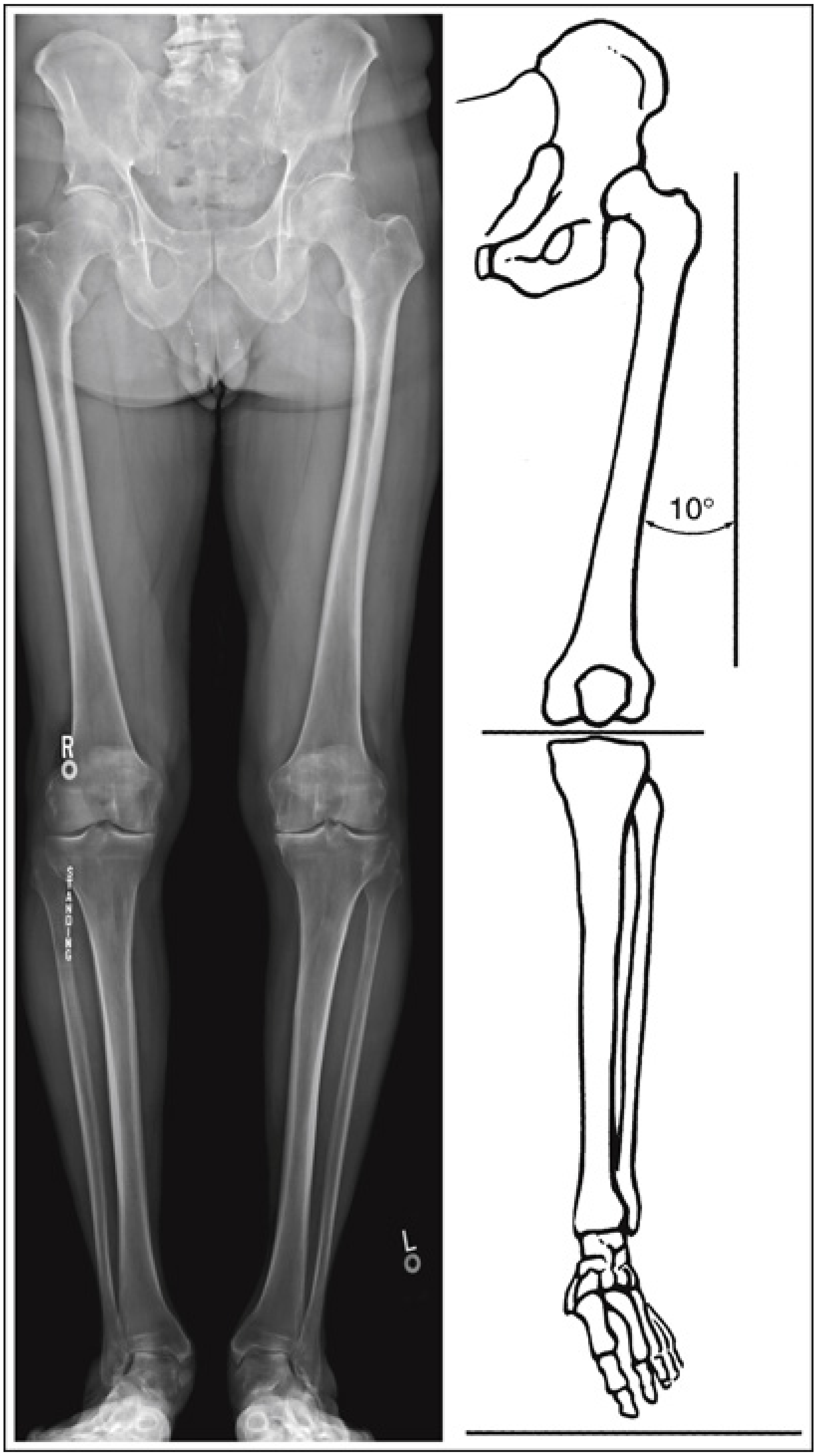


FIGURE 6.177 Demonstrating femoral inclination in the anatomical position.

Total Knee Replacement: Lateral Femoral Condyle in Joint Space

A TKR lateral knee obtained with excessive cephalic CR angulation demonstrates the lateral femoral component in the knee joint space, causing it to be narrowed or closed, and the fibular head situated distal to the plastic tibial tray (**Fig. 6.184**).

Knee Rotation: Anterior and Posterior Alignment of Femoral Condyles

Alignment of the anterior and posterior margins of the femoral condyles is accomplished on a lateral knee by placing the femoral epicondyles perpendicular to the IR and accurately aligning the CR with the femur. As discussed, the medial condyle is positioned distal to the lateral condyle when the patient is placed in the recumbent position. It is also positioned posterior to the lateral condyle when the femoral epicondyles are aligned perpendicular to the IR. To obtain alignment of the anterior and posterior condylar margins, the medial condyle must be projected proximally and anteriorly onto the lateral condyle and is accomplished by aligning the CR with a 30-degree angle with the long axis of the femur, as illustrated in **Fig. 6.185**. When aligning the CR, think about what you need the angle to do and align it so it does just that; move the medial condyle proximally and anteriorly. This method more accurately visualizes the tibia superimposing one-half of the fibular head, which is 90 degrees from the AP projection.

Alternate Positioning Method

An alternate method of obtaining anterior and posterior alignment of the femoral condyles is to align the femoral epicondyles perpendicular to the IR, and then roll the patella toward the IR approximately 0.25 inch (0.6 cm) to move the medial condyle anteriorly onto the lateral condyle. Next, align the CR with the long axis of the femur, as shown in **Fig. 6.186**. This CR

alignment will move the medial condyle only proximally and demonstrates the fibular head without tibial superimposition (**Fig. 6.187**). Regardless of the method your facility prefers, a true lateral knee projection has not been obtained unless all aspects of the condyles are superimposed.

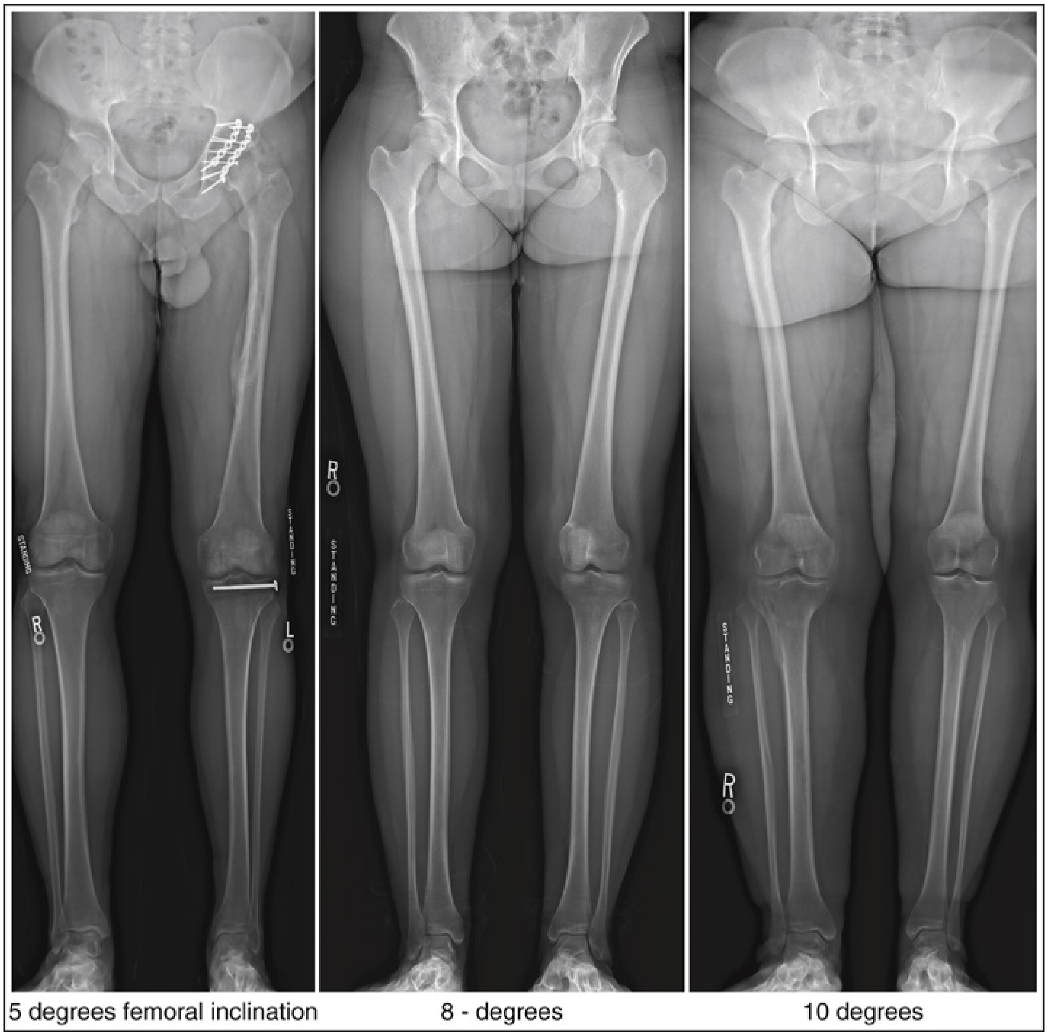


FIGURE 6.178 AP long leg projections to demonstrate the differing degrees of femoral inclination due to the variation in pelvis width and femoral length, causing a need for different CR angulations to obtain a lateral knee projection with an open knee joint space.

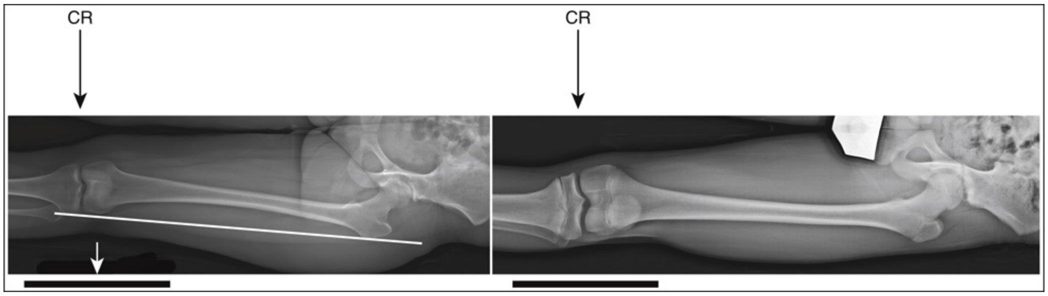


FIGURE 6.179 Lateral femur projections to demonstrate the loss of femoral inclination that occurs when the patient is placed recumbent for a lateral knee projection.

Internal Knee Rotation: Medial Condyle Posterior to Lateral Condyle

When a lateral knee projection is obtained that demonstrates the adductor tubercle and medial condyle posterior to the lateral condyle, the patella was situated too far from the IR (knee internally rotated; **Figs. 6.188** and **6.189**).

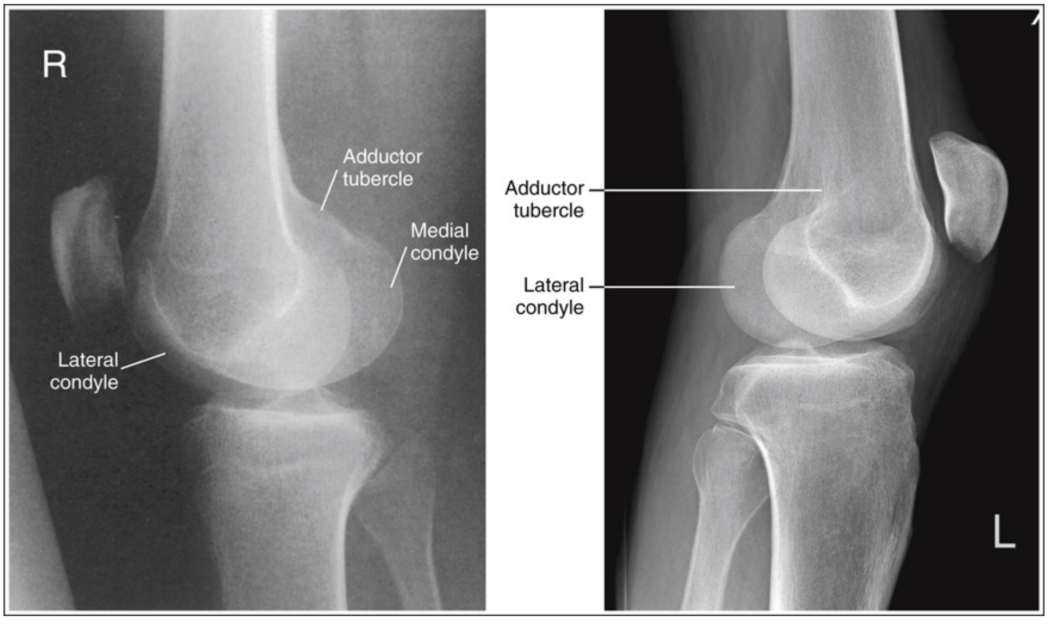


FIGURE 6.180 Identifying the medial condyle using the adductor tubercle.

FIGURE 6.181 Lateral knee projection taken without a cephalic CR angulation.

External Knee Rotation: Medial Condyle Anterior to Lateral Condyle

When a lateral knee projection is obtained that demonstrates the medial condyle anterior to the lateral condyle, the patella was situated too close to the IR (leg externally rotated; **Figs. 6.190** and **6.191**).

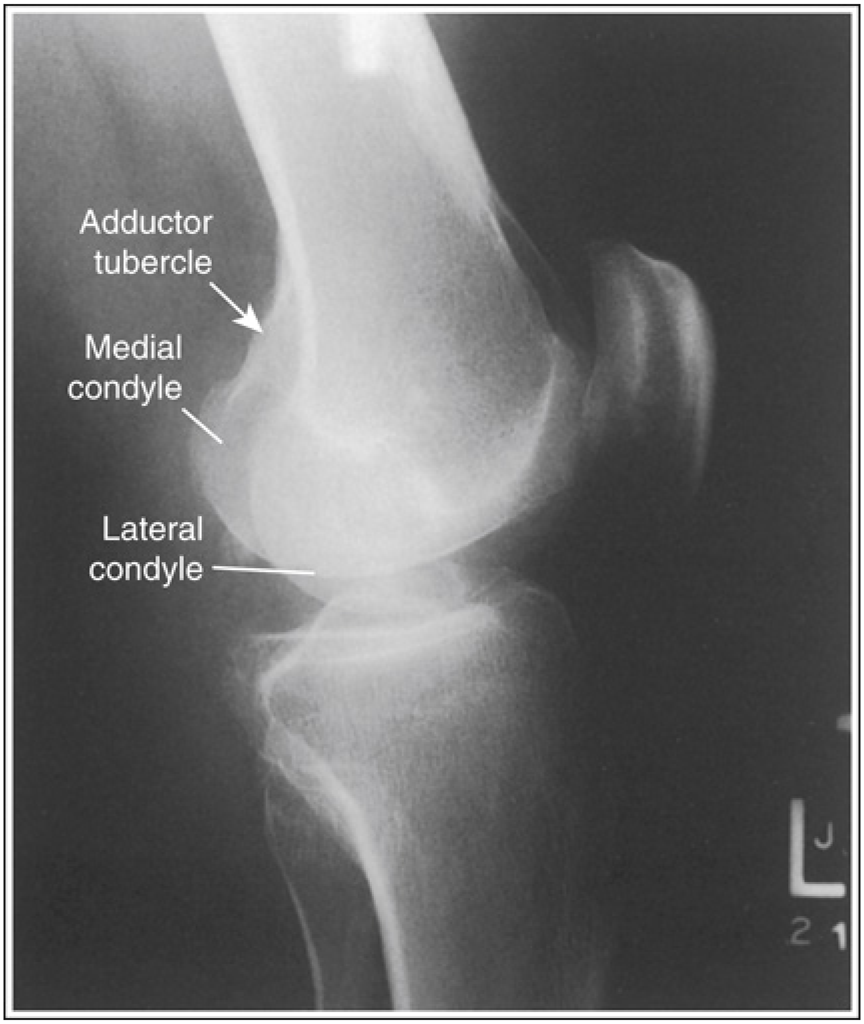


FIGURE 6.182 Lateral knee projection taken with excessive cephalic CR angulation.

Total Knee Replacement: Rotation

When a TKR lateral knee projection is obtained with rotation, the medial and lateral femoral pegs and the femoral component are not aligned anteriorly and posteriorly. It is often difficult to identify the adductor tubercle so the proximal tibial and fibular relationship is best to use when determining the direction of the rotation.

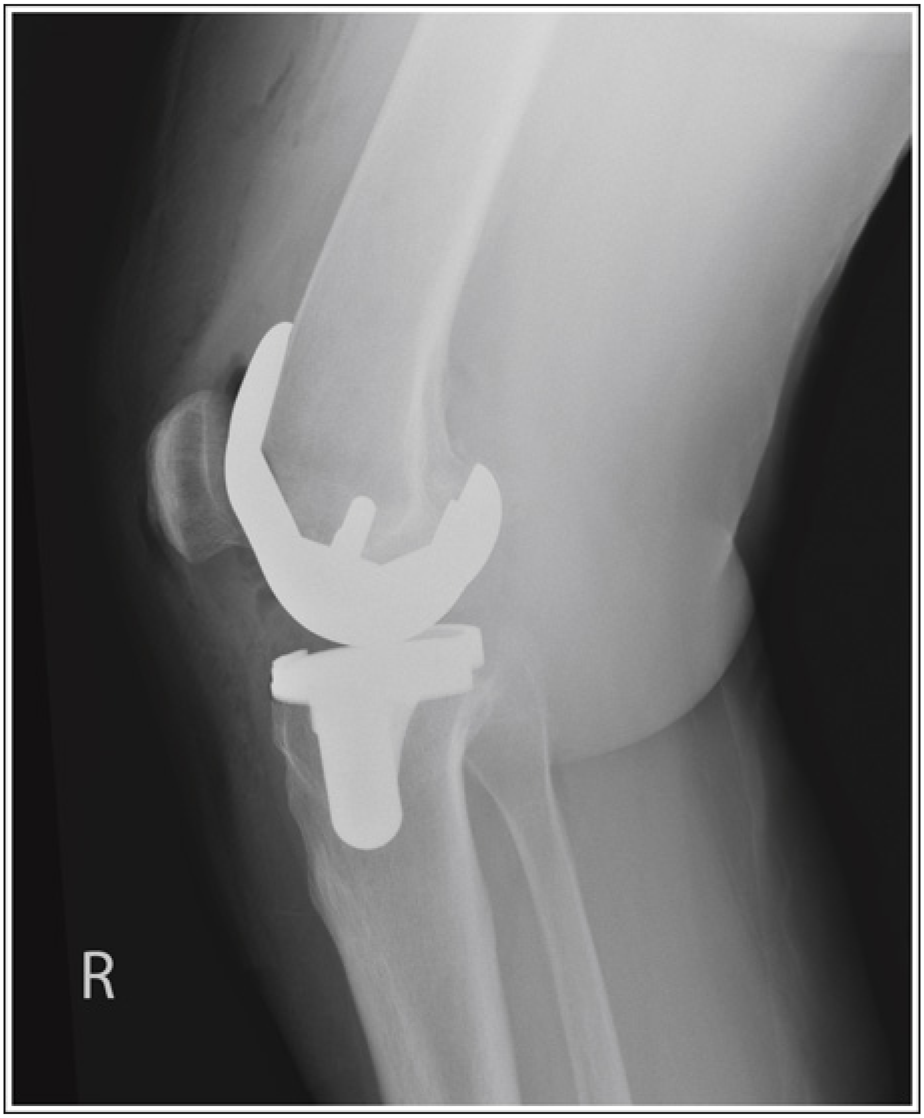


FIGURE 6.183 TKR lateral knee projection taken with the medial condyle in the joint space due to using insufficient cephalic CR angulation.

FIGURE 6.184 TKR lateral knee projection with the lateral condyle in the joint space due to using excessive cephalic CR angulation.

- *When the cephalic CR is aligned at a 30-degree angle with the femur* as described above, and the patella is positioned too far from the IR, the tibia superimposes more than half of the fibular head on the resulting projection (see **Fig. 6.189**), and if the patella is

positioned too close to the IR, the tibia will superimpose less than half of the fibular head (**Fig. 6.192**).

FIGURE 6.187 Lateral knee projection obtained with alternate CR alignment shown in **Fig. 6.186**.

FIGURE 6.188 Poorly positioned lateral knee projection with patella too far from the IR (leg internally rotated).

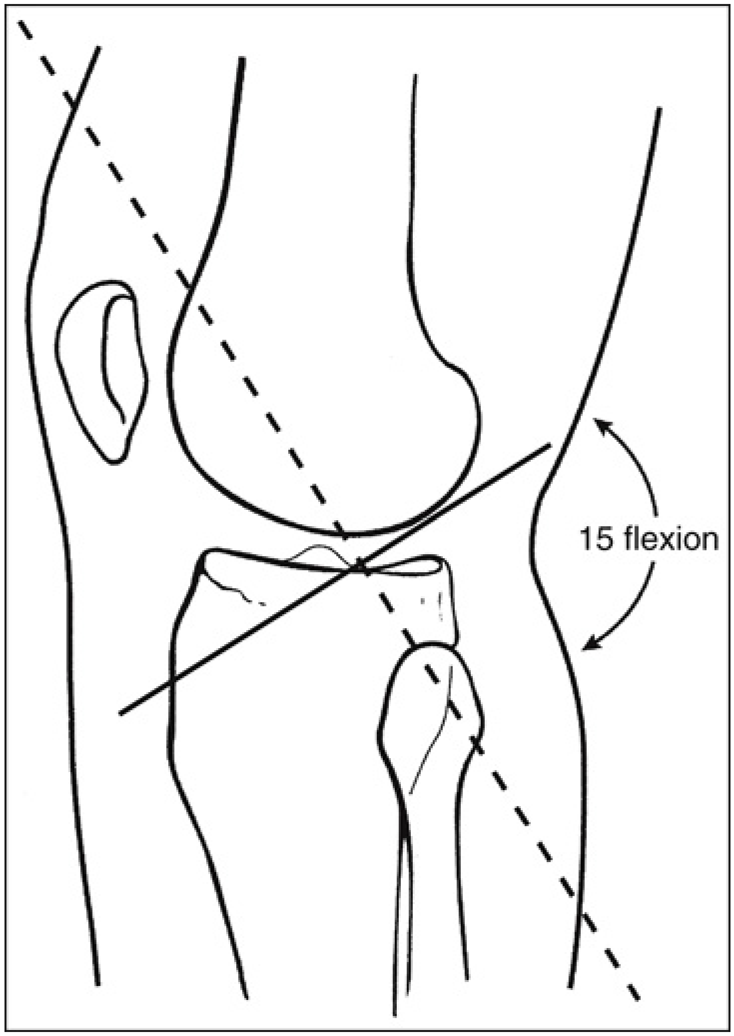


FIGURE 6.185 CR aligned with femur for lateral knee projection.

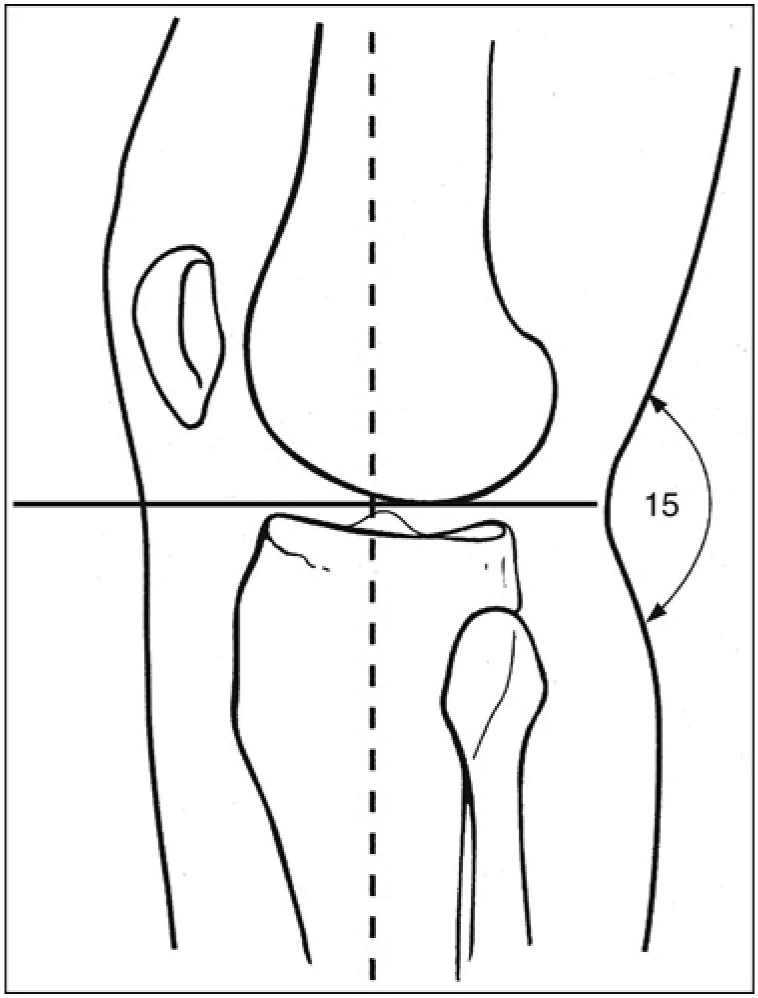


FIGURE 6.186 Alternate CR alignment for lateral knee projection.

- *When the cephalic CR is aligned with the femur as described above, and* the patella is positioned too far from the IR, the tibia will superimpose some amount of the fibular head (**Fig. 6.193**), and if the patella is positioned too close to the IR, the fibular head will be seen without tibial superimposition on the resulting projection (see **Fig. 6.191**).

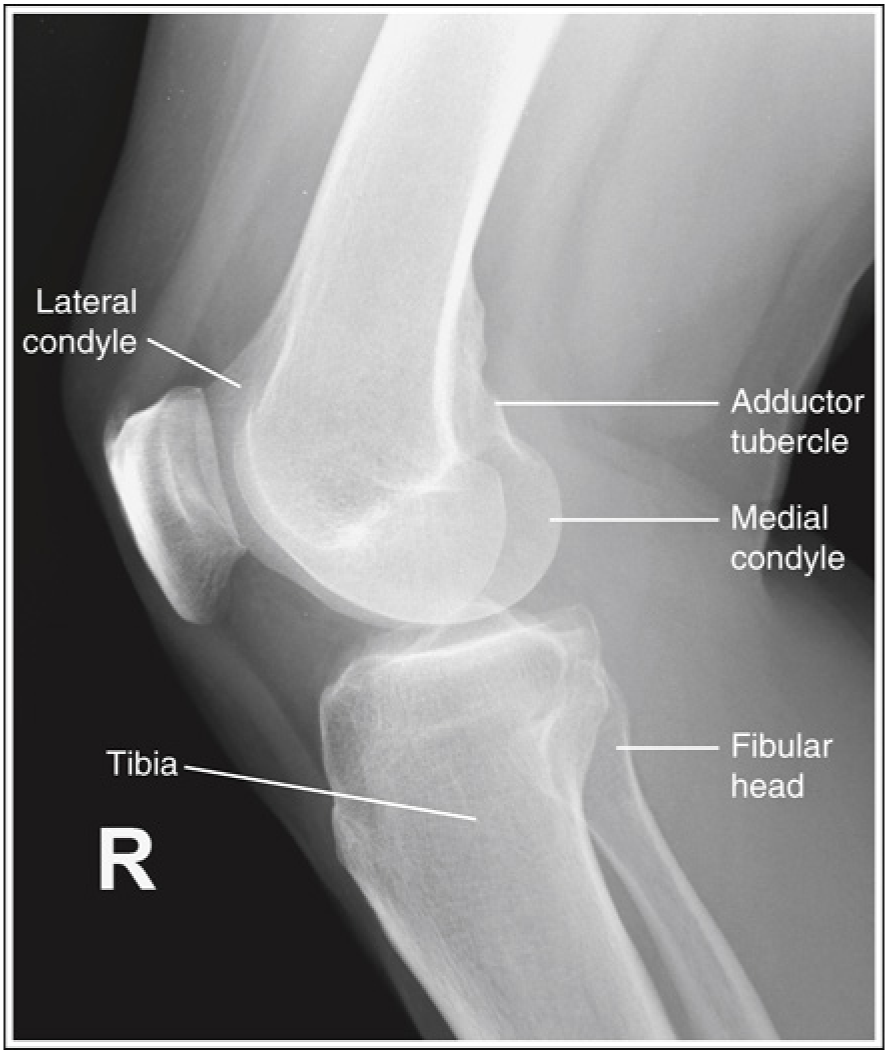


FIGURE 6.189 Lateral knee projection taken with leg internally rotated.

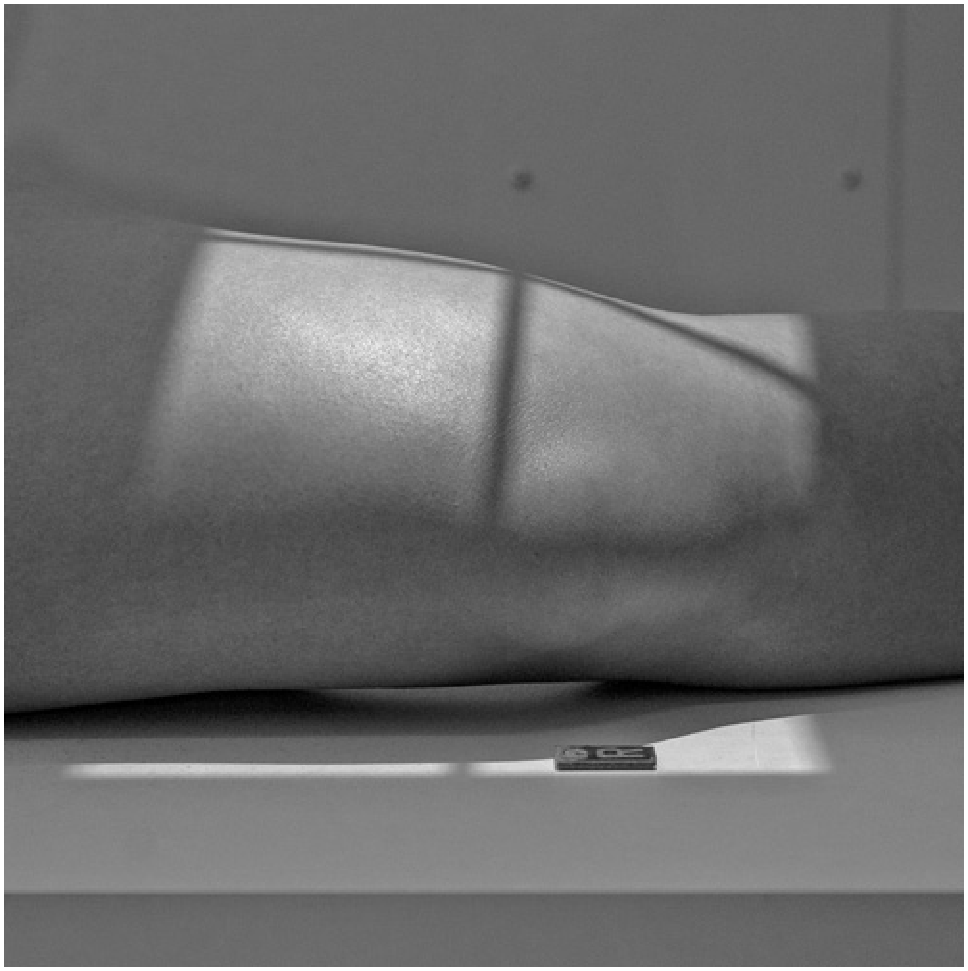


FIGURE 6.190 Poorly positioned lateral knee projection with patella too close to IR (leg externally rotated).

Knee Rotation: Knee Flexion

It should also be noted that the tibiofibular relationship should not be used to determine repositioning when the knee is flexed close to 90 degrees (**Fig. 6.194**). With high degrees of knee flexion, it is proximal and distal femoral elevation and depression that determine the tibiofibular relationship, not leg rotation. To understand this change best, view the skeletal leg in a lateral projection with 90 degrees of leg flexion. Observe how the tibiofibular

relationship results in increased tibial superimposition of the fibula when the distal femur is elevated and in decreased tibial superimposition of the fibula when the distal femur is depressed.

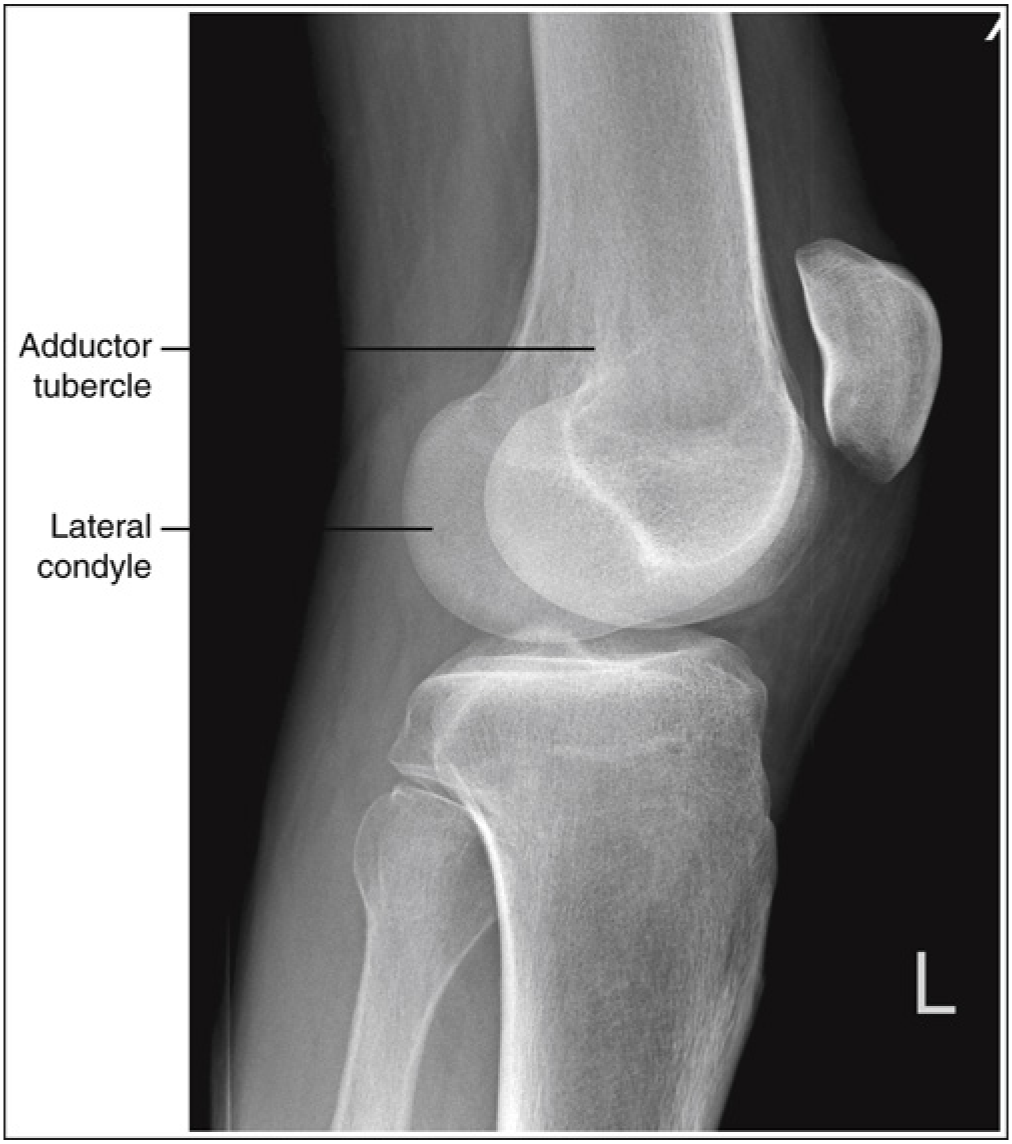


FIGURE 6.191 Lateral knee projection taken with leg externally rotated.

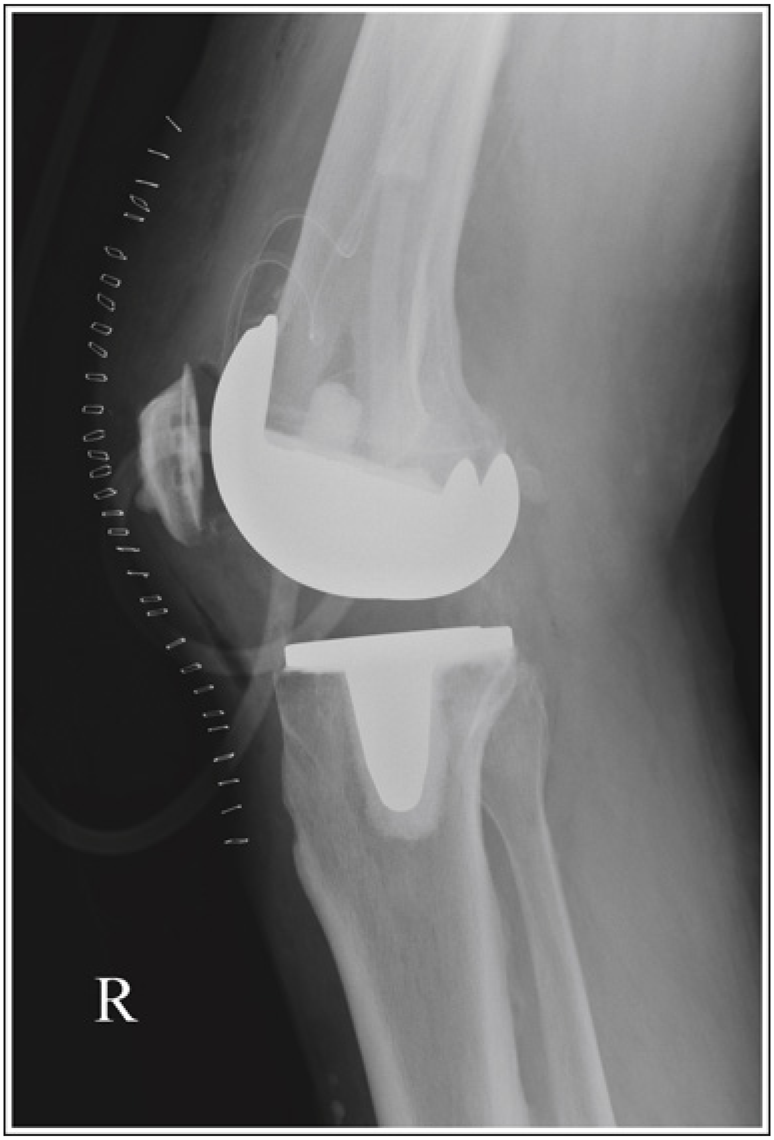


FIGURE 6.192 TKR lateral knee projection with leg externally rotated.

FIGURE 6.193 TKR lateral knee projection with internal rotation.

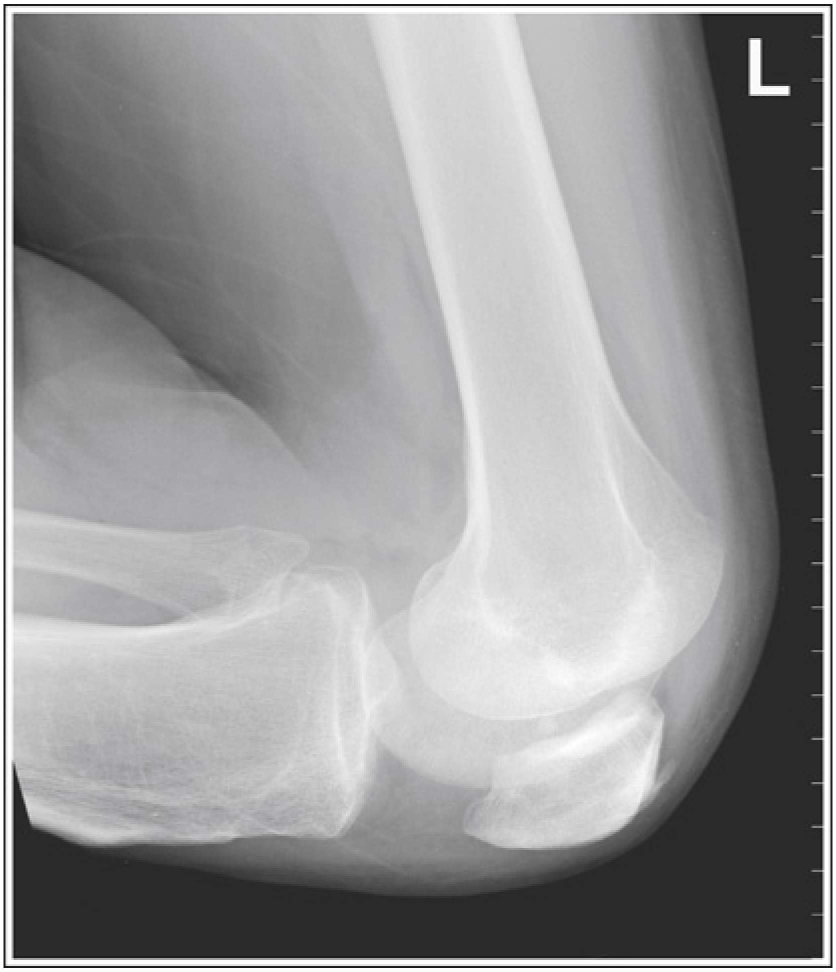


FIGURE 6.194 Lateral knee projection taken with the knee flexed to 90 degrees.

FIGURE 6.195 Alignment of the hip and knee joints for crosstable lateral knee projection.

Supine (Crosstable) Lateromedial Knee Projection: Distal Femoral Condyle Alignment

When a lateromedial knee projection is taken with the patient supine because of trauma or other patient condition, and using a horizontal CR, the CR angulation described in the preceding recumbent lateral knee is not required, as long as the femoral inclination is not reduced or increased by abduction and adduction of the leg and the CR aligns with the distal femoral condyles. This means that the long axis of the femur will not be aligned parallel with the IR when the leg is accurately placed in anatomical position with the hip and knee joints aligned (**Fig. 6.195**).

- *If the leg is abducted for a crosstable lateromedial knee projection,* aligning the knee joint lateral to the hip joint, the medial femoral condyle will be distal to the lateral condyle, the knee joint space will be narrowed or closed, and the fibular head positioned less than 0.5 inch (1.25 cm) distal from the tibial plateau on the resulting projection (**Fig. 6.196**). This projection error will also be demonstrated if the hip and knee joints are aligned and the CR directed proximally (tube column rotated toward head).
- *If the leg is adducted for a crosstable lateromedial knee projection,* placing the knee joint medial to the hip joint, the lateral femoral condyle will be distal to the medial condyle, the knee joint space will be narrowed or closed, and the fibular positioned more than 0.5 inch (1.25 cm) distal from the tibial plateau on the resulting projection (**Fig. 6.197**). This error will also be demonstrated if the hip and knee joints are aligned and the CR directed distally (tube column rotated toward feet).

Supine (Crosstable) Lateromedial Knee Projection: External Leg Rotation

If the patient is unable to internally rotate the leg to place the femoral epicondyles perpendicular to the IR, the anterior and posterior margins of the femoral condyles will not be aligned. To accomplish this alignment, elevate the leg on a radiolucent sponge and angle the CR anteriorly until it is aligned parallel with the femoral epicondyles. If a grid is used, make certain that the grid is adjusted so that the gridlines are running with the CR angulation to prevent grid cutoff. Failure to align the CR and epicondyles will result in a projection that demonstrates the medial condyle anterior to the lateral condyle (**Fig. 6.198**).

Positioning for a Dislocated Knee

Although the dislocated lateral knee projection will not demonstrate the femoral condyles and the tibial plateau in alignment, the goal is to obtain a projection that as closely as possible fulfills the analysis guidelines as listed in **Table 6.17** (**Fig. 6.199**).

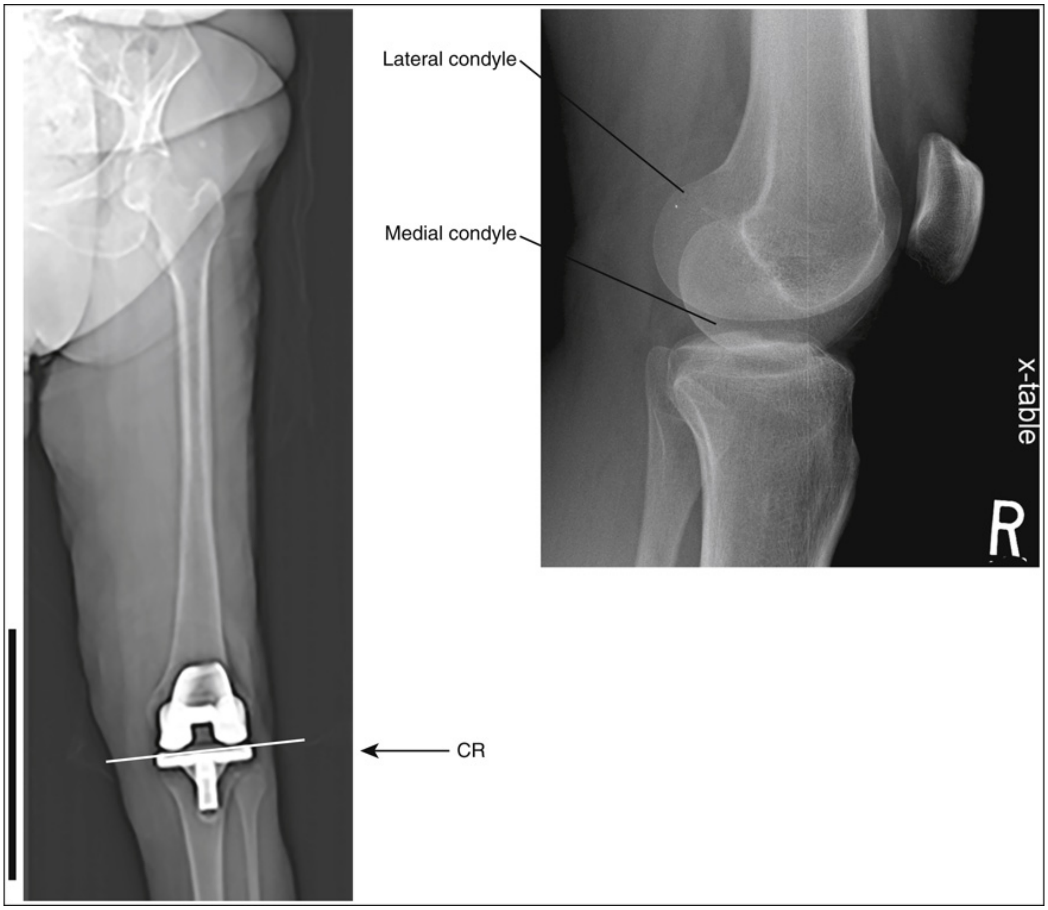


FIGURE 6.196 Crosstable lateromedial knee projection taken with the leg abducted. To prevent a closed knee joint on a patient that is unable to abduct the leg, angle the CR distally until it is parallel with the palpable femoral epicondyles, center to the knee joint, and align the IR perpendicular with the CR.

FIGURE 6.197 Crosstable lateromedial knee projection taken with leg adducted or CR directed distally.

FIGURE 6.198 Crosstable lateromedial knee projection with leg in external rotation.

FIGURE 6.199 Crosstable lateromedial knee projection of dislocated knee.

Lateral Knee Analysis Practice

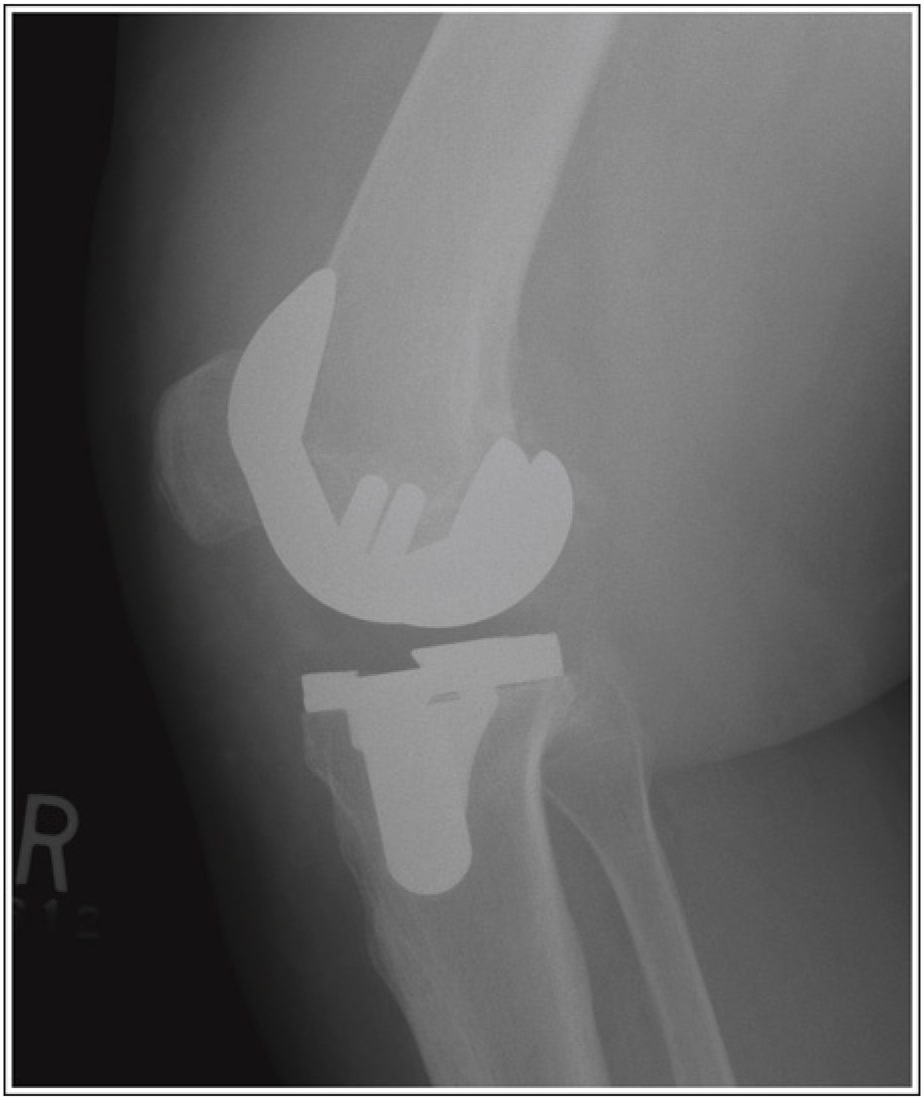


IMAGE 6.33

CR ALIGNED AT 30-DEGREE ANGLE WITH FEMUR.

Analysis

The medial condyle is anterior to the lateral condyle and the tibia superimposes less than half of the fibular head. The leg was externally

rotated.

Correction

Internally rotate the leg until the femoral epicondyles are perpendicular to the IR.

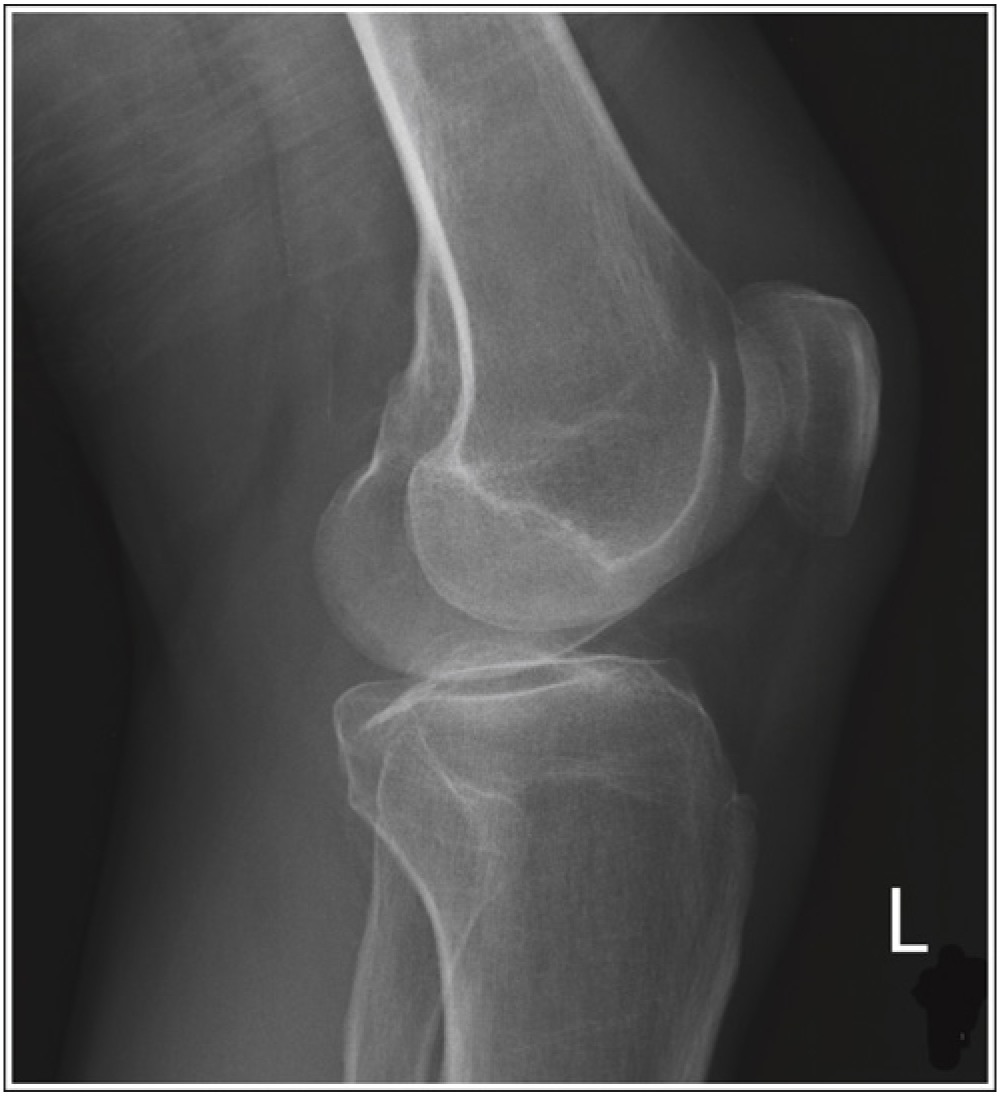


IMAGE 6.34

CR ALIGNED AT 30-DEGREE ANGLE WITH FEMUR.

Analysis

The medial femoral condyle is distal to the lateral condyle and the fibular head is less than 0.5 inch (1.25 cm) from the tibial plateau. The CR was not

angled enough cephalically. The medial condyle is posterior to the lateral condyle and the tibia superimposes more than half of the fibular head. The leg was internally rotated.

Correction

Angle the CR cephalically (usually requires only a 5-degree adjustment) and externally rotate the leg until the femoral epicondyles are perpendicular to the IR.

IMAGE 6.35

CROSSTABLE LATEROMEDIAL PROJECTION.

Analysis

The medial femoral condyle is distal to the lateral condyle, the knee joint space is closed, and the fibular head is positioned less than 0.5 inch (1.25

cm) distal from the tibial plateau. The leg was abducted or the CR angle was too cephalic. The medial condyle is anterior to the lateral condyle and the tibia is demonstrated without tibial superimposition. The leg was externally rotated.

Correction

Adduct the leg until the hip and knee joints are aligned or angle the CR distally (rotate tube column toward the feet) 5 degrees and internally rotate the leg or angle the CR anteriorly until the CR parallels the femoral epicondyles.

Intercondylar Fossa: PA Axial Projection (Holmblad Method and Weight-Bearing Bilateral Flexed)

See **Table 6.18** and Figs. **6.200**–**6.203**.

Medial and Lateral Intercondylar Fossa: Knees Closer Than Hip Width or Leg Externally Rotated

As discussed in the lateral knee projection, the femurs incline medially to position the knees below the hip joints and provide stability and balance (see **Fig. 6.177**). If the degree of medial femoral inclination is increased by positioning the knees closer together than hip width, positioning the distal femurs too medially to the hip joints or the proximal femurs too laterally to the knee joints for PA axial and weight-bearing flexed knees, the medial and lateral aspects of the intercondylar fossa are not superimposed, the patella is situated laterally, and more than one half of the fibular head superimposes the tibia on the resulting projection (**Fig. 6.204**). This same projection will result when the knees are placed hip width apart, but the leg is externally

rotated. For the Holmblad, this is accomplished when the heel is allowed to rotate medially.

TABLE 6.18

BOS, Base of support; *COG*, center of gravity; *CR*, central ray; *IR*, image receptor.

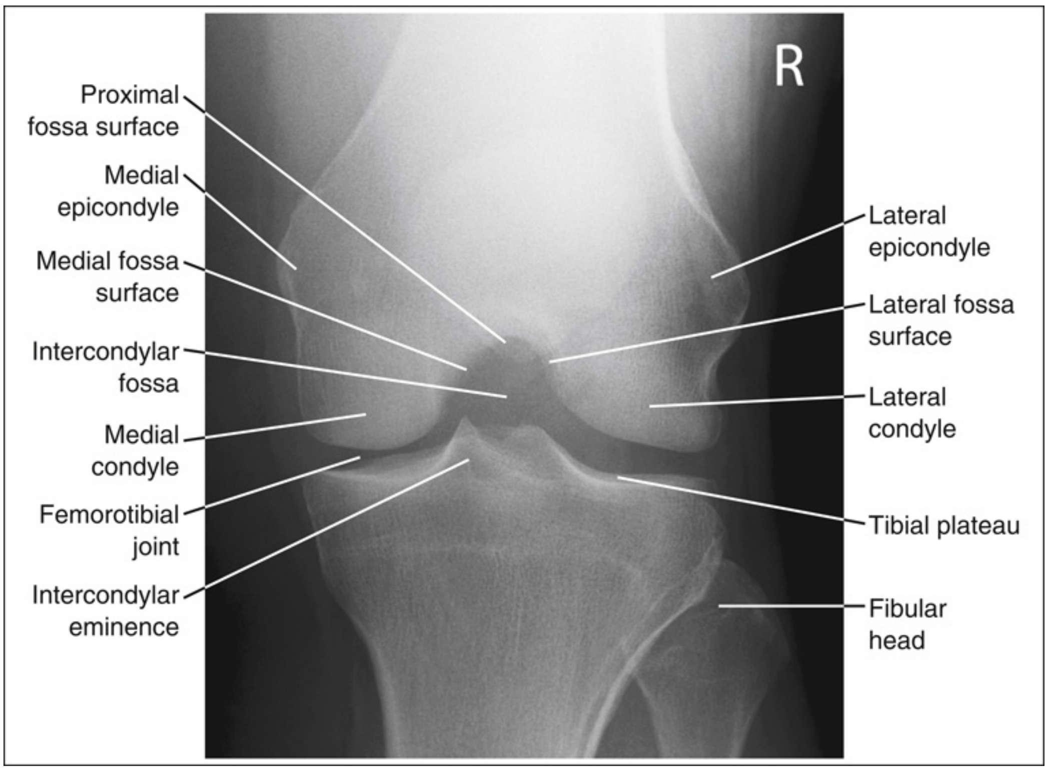


FIGURE 6.200 PA axial knee projection (Holmblad method) with accurate positioning.

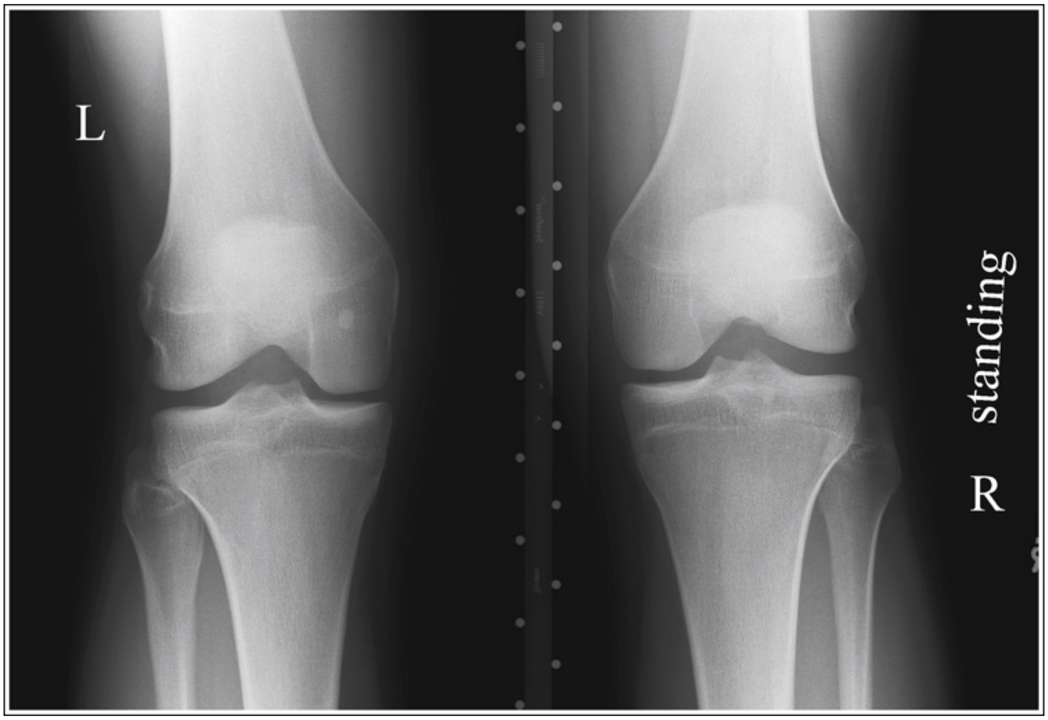


FIGURE 6.201 Bilateral weight-bearing PA axial flexed knee projection with accurate positioning.

Medial and Lateral Intercondylar Fossa: Knees Wider Than Hip Width or Leg Internally Rotated

If the degree of medial femoral inclination is increased by positioning the knees wider apart than hip width, placing the distal femurs too laterally to the hip joints or the proximal femurs too medially to the knee joints for PA axial and weight-bearing flexed knees, the medial and the lateral aspects of the intercondylar fossa are not superimposed, the patella is situated medially, and less than one-half of the fibular head superimposes the tibia on the resulting projection (**Fig. 6.205**). This same projection will result when the knees are placed hip width apart but the leg is internally rotated. For the Holmblad this is accomplished when the heel is allowed to rotate laterally.

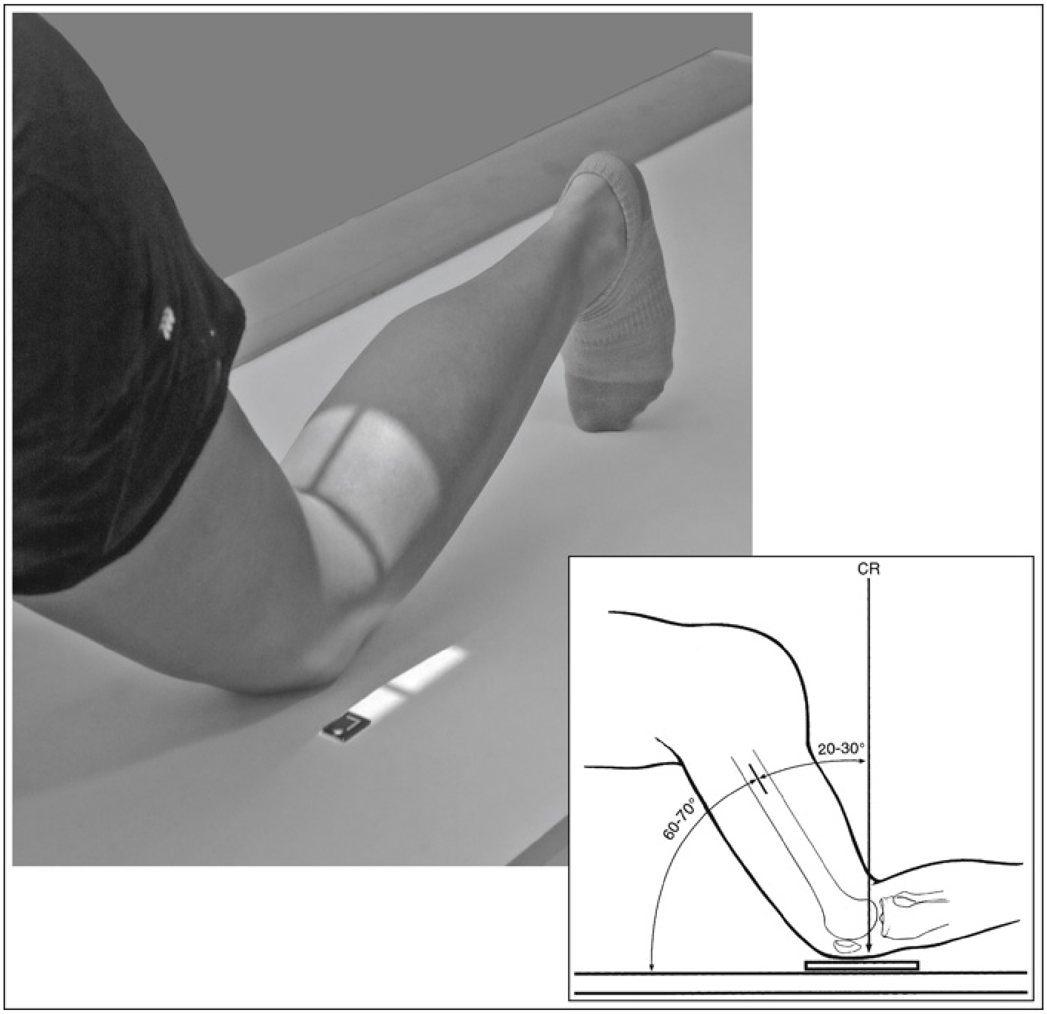


FIGURE 6.202 Proper patient positioning for PA axial knee projection (Holmblad method).

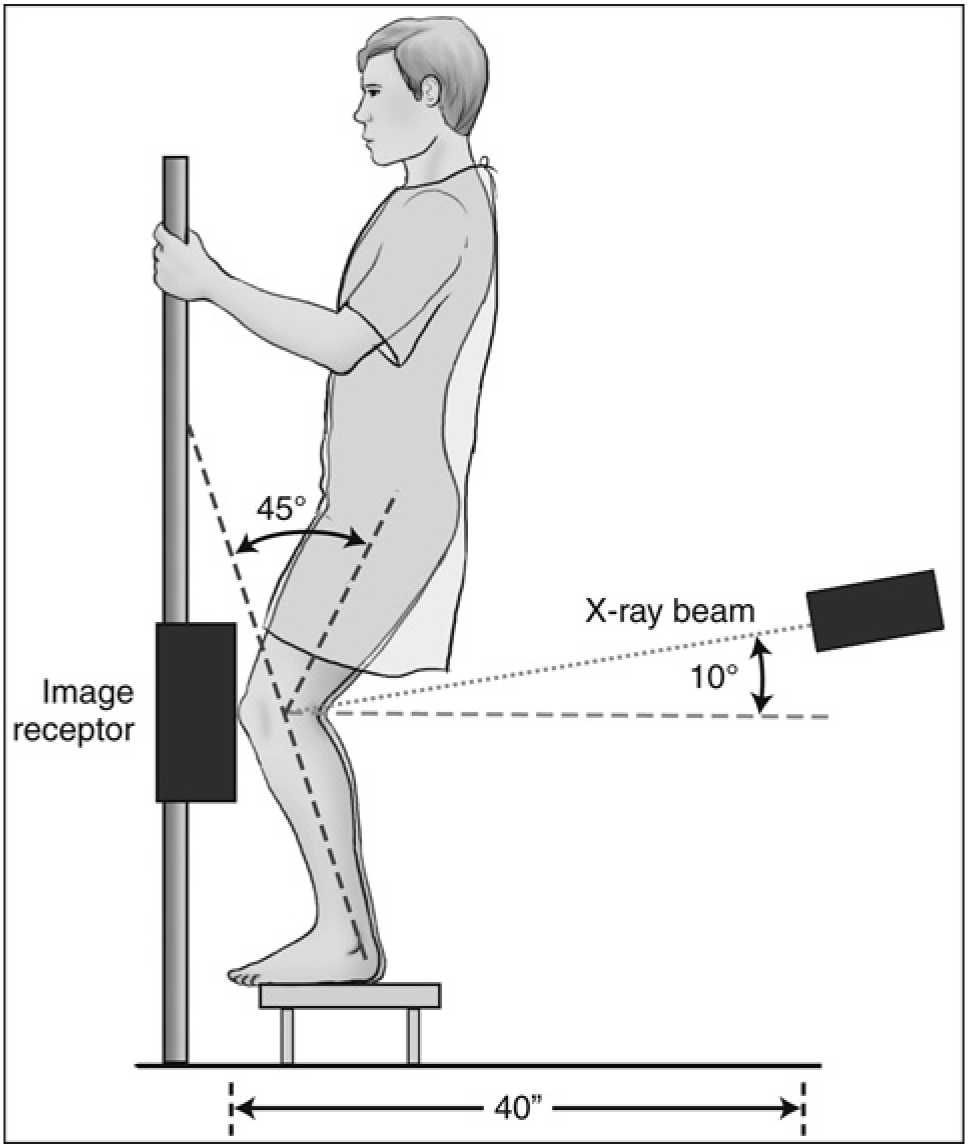


FIGURE 6.203 Proper patient positioning for the weight-bearing bilateral PA flexed axial knee projection (Rosenberg method).

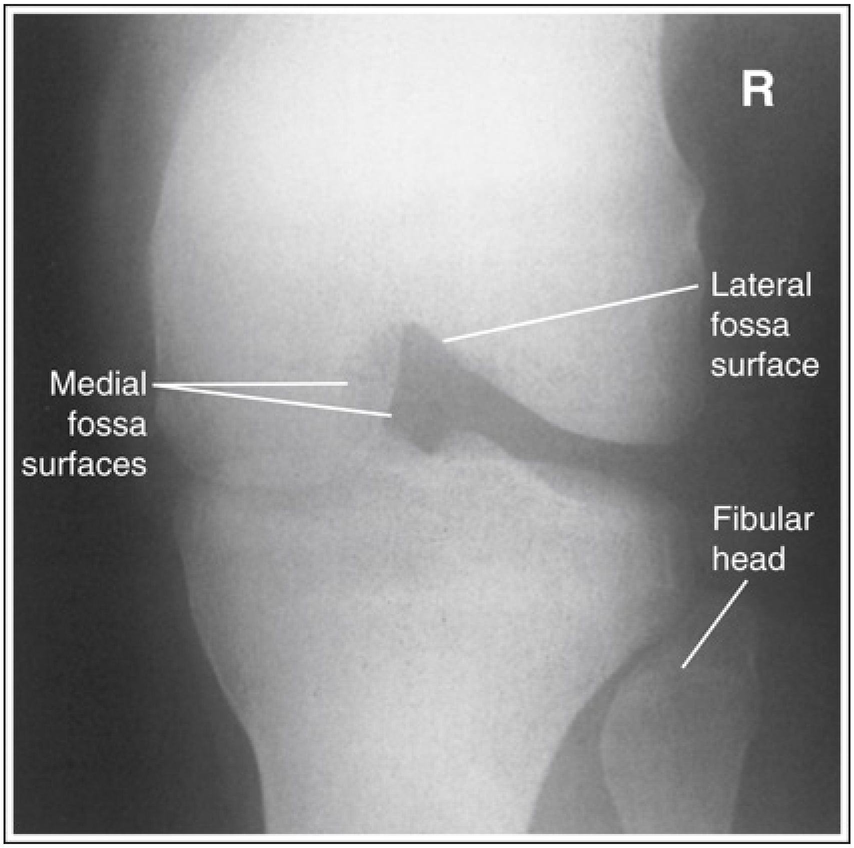


FIGURE 6.204 PA axial knee projection (Holmblad method) taken with the knees closer together than hip width or with the heel laterally rotated.

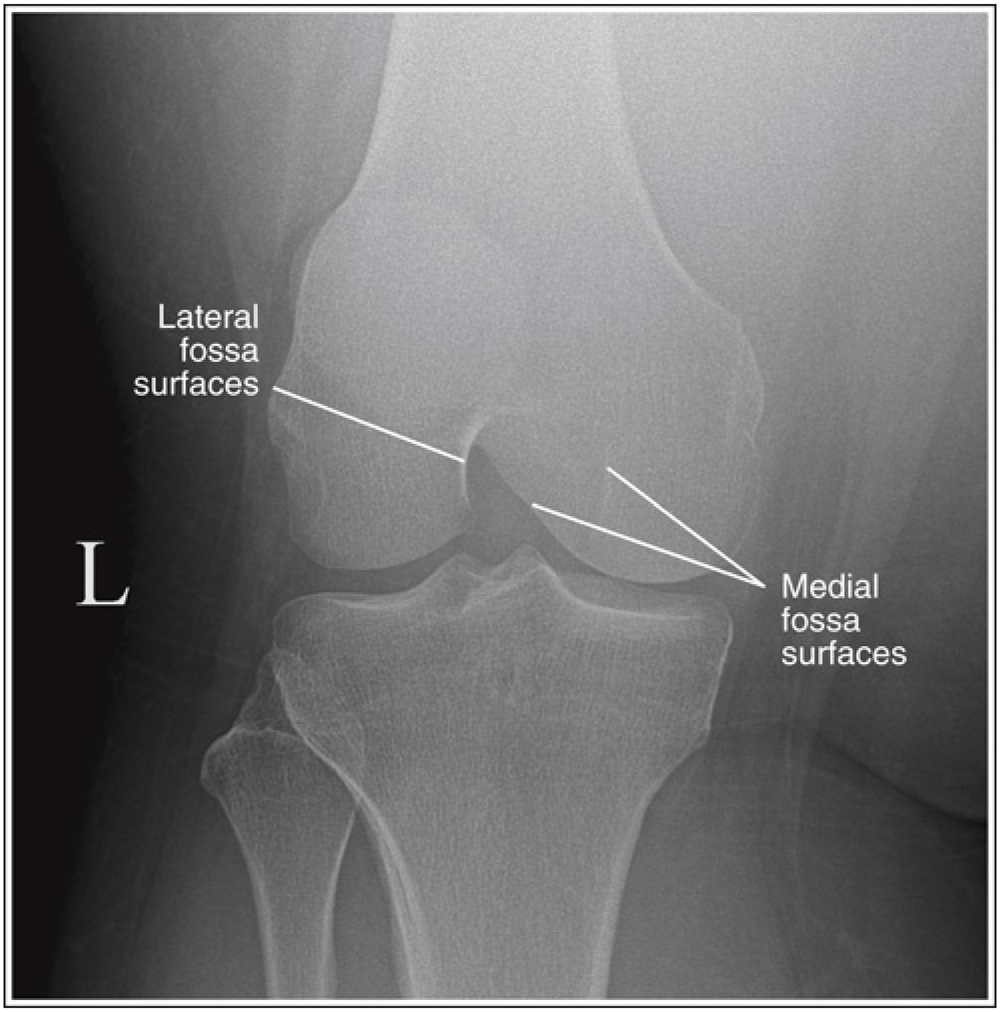


FIGURE 6.205 PA axial knee projection (Holmblad method) taken with the knees wider than hip width or the heel rotated medially and with the distal lower leg elevated.

Weight-Bearing Bilateral Flexed: CR Off-Centering Versus External Rotation

For weight-bearing bilateral flexed PA axial knee projections the CR is centered between the knees. This off-centering of the CR results in laterally diverged x-rays recording the knees and causing the resulting projection to appear as if the legs were in external rotation for the projection and

demonstrating a larger appearing medial femoral condyle when compared with the lateral (**Fig. 6.206**). The farther apart the knees are positioned from each other, the greater the amount of lateral divergence and the more laterally rotated the knees will appear. This appearance can be offset by estimating the degree of x-ray divergence (2 degrees for every 1 inch of off-center) and increasing the degree of internal rotation of the legs from the standard positioning by the same degree.

Femoral Tilt With the IR: Intercondylar Fossa Visualization

If the knee is flexed in a PA projection so that the proximal femur moves away from the IR, increasing the tilt between the long axis of the femur and IR, the amount of the intercondylar fossa that is demonstrated increases and the placement of the patella in relationship to the intercondylar fossa changes as demonstrated in **Fig. 6.147**. The degree of femoral tilt with the IR is the same for AP and PA projections; however, the distal femur is positioned closer to the IR for an AP projection and the proximal femur is positioned closest to the IR for a PA projection.

Holmblad Method: Excessive Femur to IR Angle

If a PA axial knee projection is obtained that demonstrates the anterior and posterior cortical outlines of the proximal intercondylar fossa without superimposition, use the placement of the patella on the femur to determine whether the proximal femur was positioned too close to or too far from the IR. If the patellar apex is demonstrated within the intercondylar fossa, the femur to IR angle was too great, causing the knee to be flexed more than needed (**Fig. 6.207**).

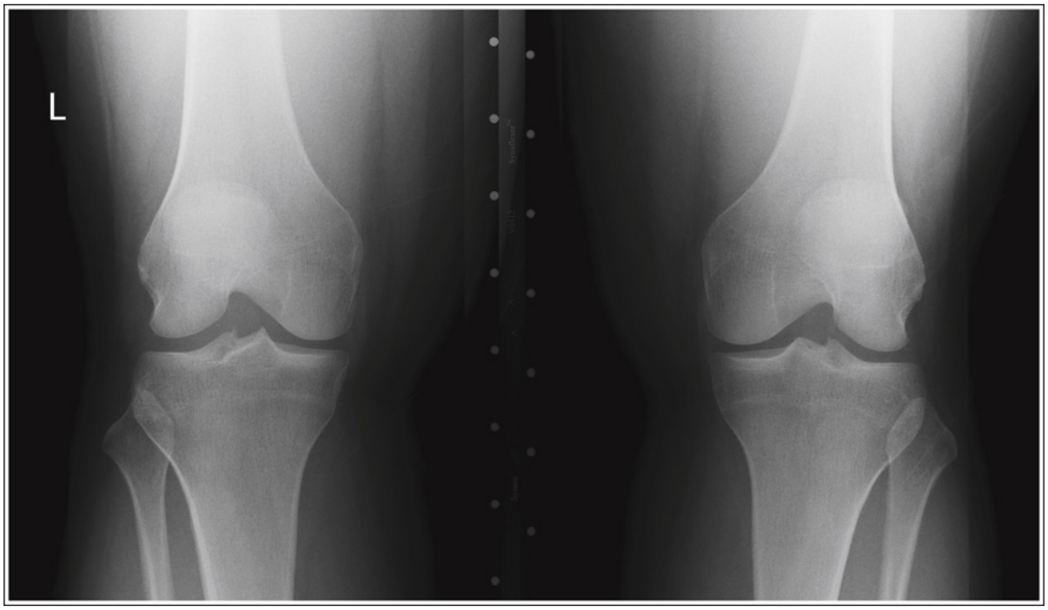


FIGURE 6.206 Weight-bearing, bilateral PA knee projection obtained without increased internal leg rotation to offset lateral beam divergence.

(Fig. 6.206).

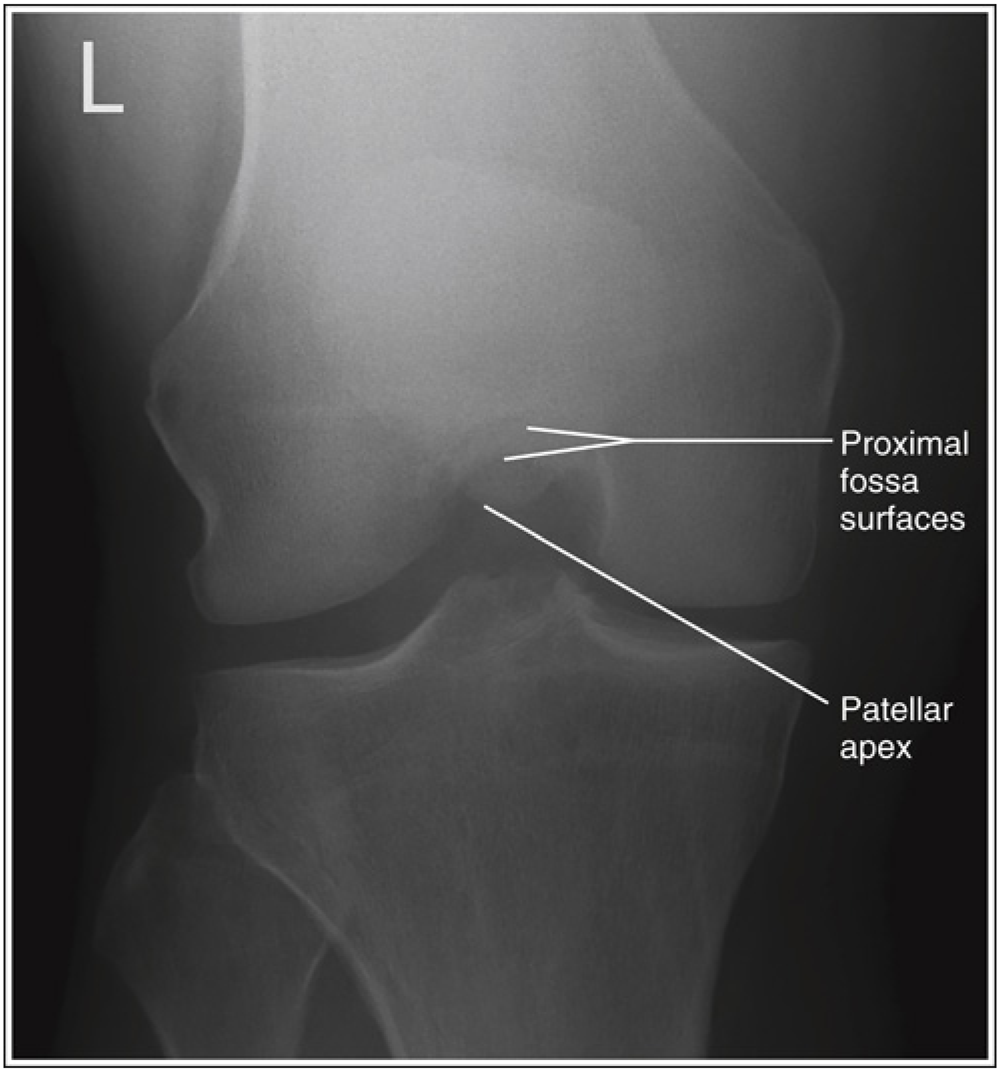


FIGURE 6.207 PA axial knee projection (Holmblad method) taken with the knee overflexed.

Holmblad Method: Insufficient Femur to IR Angle

If a PA axial knee projection is obtained that demonstrates the anterior and posterior cortical outlines of the proximal intercondylar fossa without superimposition and the patella is demonstrated proximally to the fossa, the femur to IR angle was insufficient and the knee was insufficiently flexed (**Fig. 6.208**).

Bilateral Weight-Bearing Flexed: Femoral Tilt With the IR

The PA axial weight-bearing bilateral knee projection is obtained to diagnose cartilage degeneration that causes knee joint space(s) narrowing. When the knee is flexed to bring the femoral shaft at a 45-degree tilt and the lower leg at a 15-degree tilt with the IR, the projection will demonstrate the cartilage that is most susceptible to degenerative changes and knee joint narrowing. The location of the patella in reference to the intercondylar fossa as described in **Fig. 6.147** can only be used to determine the accuracy of the femoral tilt with the IR when the lower leg tilt is at a 15-degree angle with the IR. This is because the tilt of the lower leg also affects knee flexion and patella position, but it does not affect the amount of the intercondylar fossa that is visualized. Before using the patella placement to determine if the femoral shaft tilt needs to be decreased or increased to obtain a 45-degree tilt when a poorly positioned PA axial flexed knee has been obtained, measure the distance that the fibular head is from the tibial plateau. The distance should be about 0.25 inch (0.6 cm). This distance is smaller than seen on AP knees because of the increase in magnification of the fibular head in the PA projection. If the lower leg was tilted more toward the IR, this distance will decrease and the patella will be positioned more distally when the intercondylar fossa is accurately demonstrated (**Fig. 6.209**), and if the lower leg was not tilted the required 15 degrees, the fibular head to tibial plateau distance will increase and the patella will be positioned more proximally and laterally when the intercondylar fossa is accurately demonstrated.

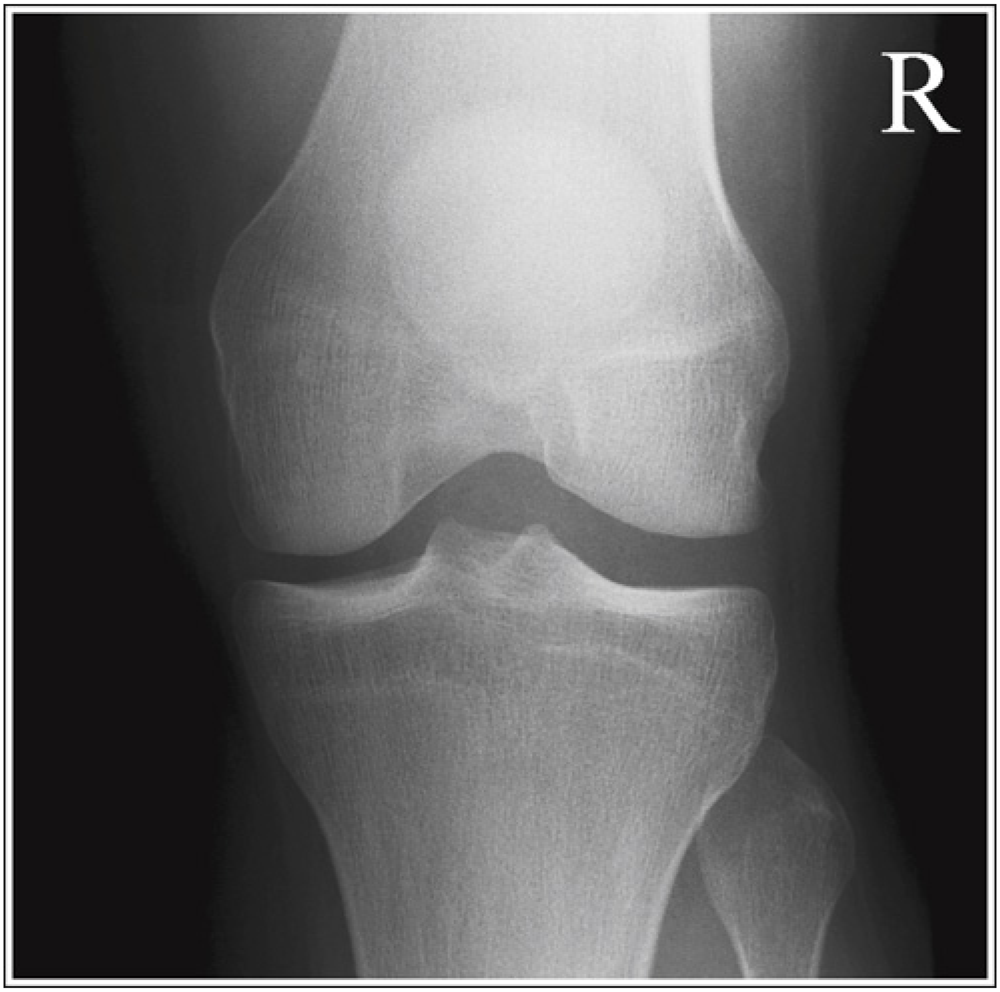


FIGURE 6.208 PA axial knee projection (Holmblad method) taken with the knee underflexed.

Weight-Bearing Bilateral Flexed: Excessive Femur to IR Angle

A PA axial weight-bearing flexed knee that demonstrates more than 0.25 inch (0.6 cm) of the proximal intercondylar fossa and the patellar apex positioned next to or in the intercondylar fossa was obtained with more than 45 degrees of femoral shaft tilt with the IR (see **Fig. 6.209**).

Weight-Bearing Bilateral Flexed: Insufficient Femur to IR Angle

A PA axial weight-bearing flexed knee that demonstrates more than 0.25 inch (0.6 cm) of the proximal intercondylar fossa and the patellar apex positioned proximal to the femoral patellar surface was obtained with less than 45 degrees of femoral shaft tilt with the IR (**Fig. 6.210**).

Holmblad Method: Insufficient Distal Lower Leg Elevation

Because the tibial plateau slopes downward from the anterior tibial margin to the posterior margin (see **Fig. 6.150**), it is necessary to elevate the distal lower leg to align the tibial plateau perpendicular to the IR and obtain an open tibiotalar joint space for a PA axial knee projection. If the resulting projection demonstrates a closed or narrowed knee joint space and the tibial plateau articulating surface, evaluate the proximity of the fibular head to the tibial plateau to determine the needed adjustment. If the fibular head is more than 0.25 inch (0.6 cm) from the tibial plateau, the distal lower leg was not elevated enough to align the tibial plateau perpendicular with the IR (**Fig. 6.211**).

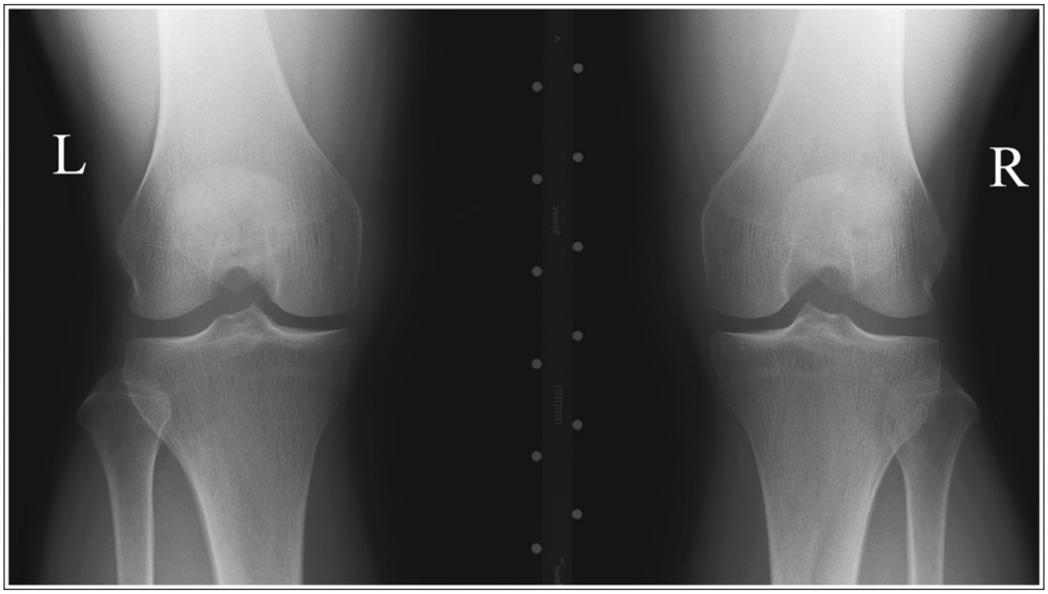


FIGURE 6.209 Bilateral weight-bearing PA axial flexed knee projection obtained with excessive femur to IR angle.

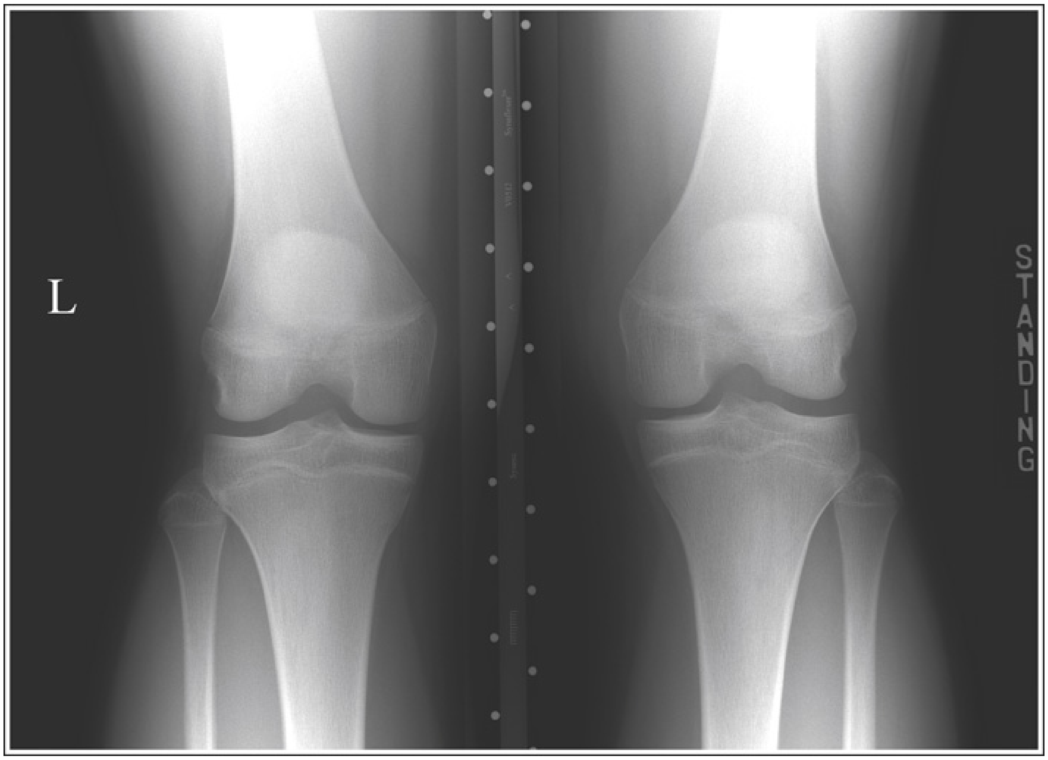


FIGURE 6.210 Bilateral weight-bearing PA axial flexed knee projection with insufficient femur to IR angle (30 degrees right knee; 45 degrees left knee).

Holmblad Method: Excessive Distal Lower Leg Elevation

If the knee joint space is narrowed or closed and the fibular head is less than 0.25 inch (0.6 cm) from the tibial plateau in a PA axial knee projection, the distal lower leg was elevated more than needed to align the proximal tibial margins (**Fig. 6.212**). The amount of lower leg adjustment required would be half the distance needed to bring the fibular head to within 0.25 inch (0.6 cm) of the tibial plateau.

Bilateral Weight-Bearing Flexed: Insufficient Lower Leg Tilt With the IR

The tilt that the lower leg makes with the IR for the PA axial weight-bearing flexed knee is determined by the distance the feet are positioned away from the IR. Typically the required 15-degree tilt will be obtained when the toes line up with the front face of the IR. If the toes are positioned beyond the IR and the lower leg is tilted less than the required 15 degrees with the IR, the resulting projection demonstrates a closed or narrowed knee joint space and the fibular head at more than a 0.25 inch (0.6 cm) distance from the tibial plateau (**Fig. 6.213**).

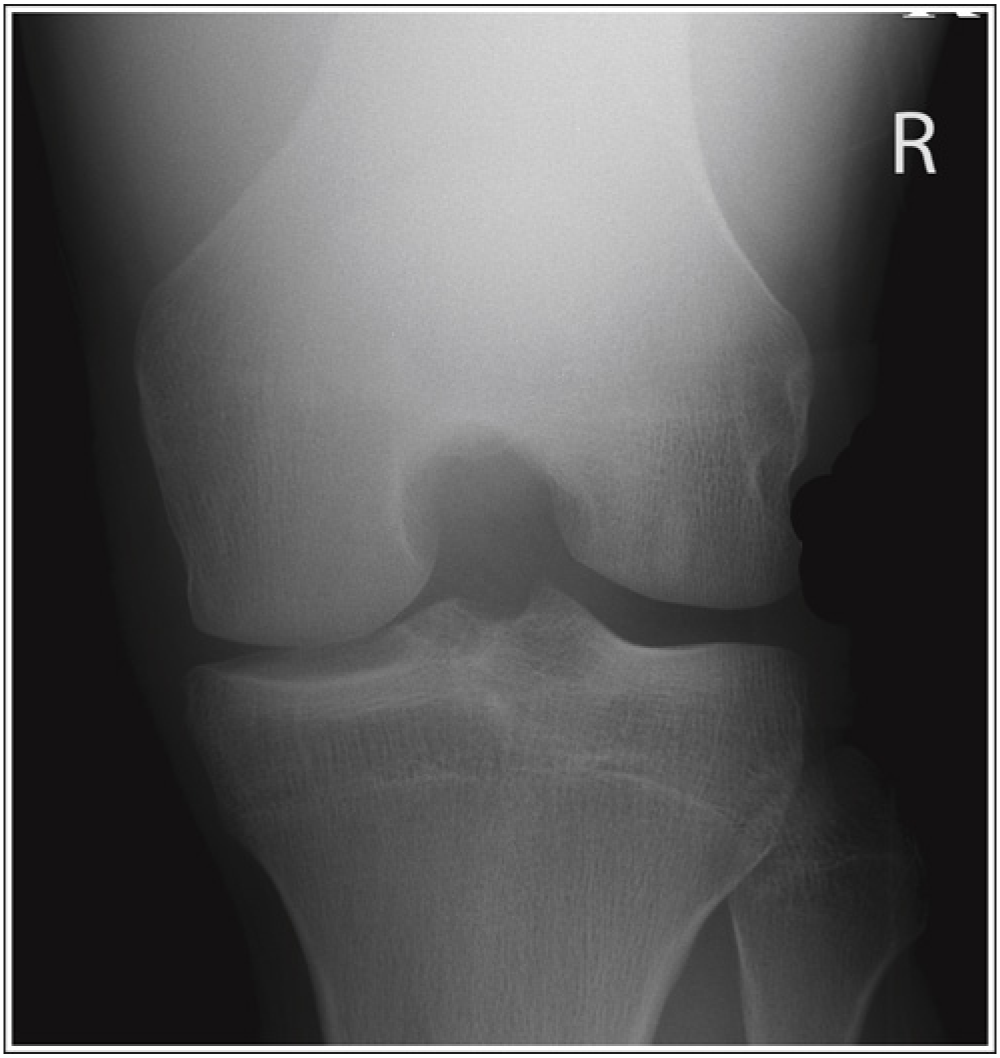


FIGURE 6.211 PA axial knee projection (Holmblad method) obtained with insufficient distal lower leg elevation.

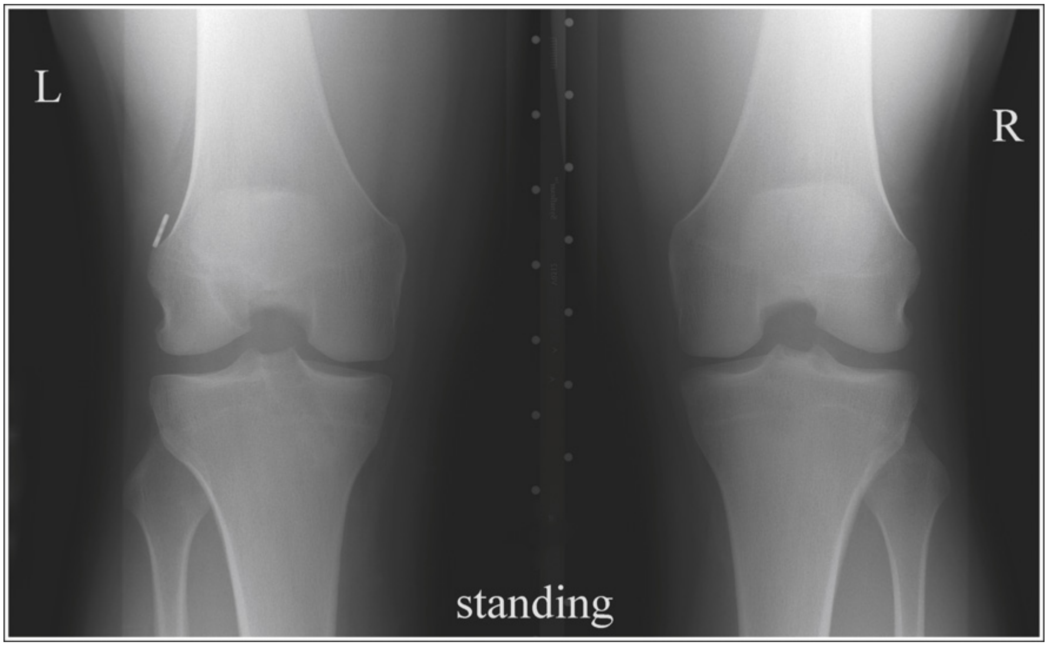


FIGURE 6.213 Bilateral weight-bearing flexed PA axial knee with insufficient lower leg tilt with IR.

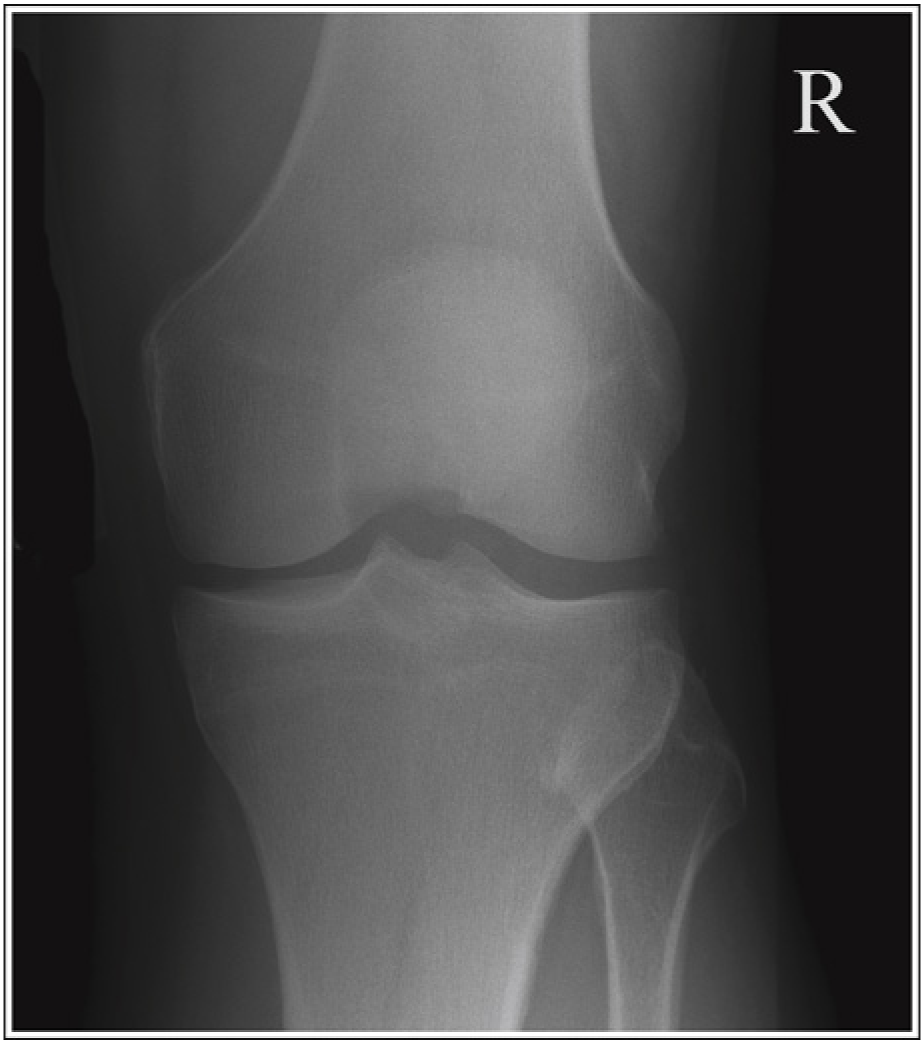


FIGURE 6.212 PA axial knee projection (Holmblad method) obtained with excessive distal lower leg elevation.

Bilateral Weight-Bearing Flexed: Excessive Lower Leg Tilt With the IR

If a PA axial weight-bearing flexed knee is obtained with the toes positioned too far away from the IR and the lower leg is tilted more than the required 15 degrees with the IR, the resulting projection demonstrates a closed or narrowed knee joint space and the fibular head is at less than a 0.25 in (0.6 cm) distance from the tibial plateau on the resulting projection (**Fig. 6.214**).

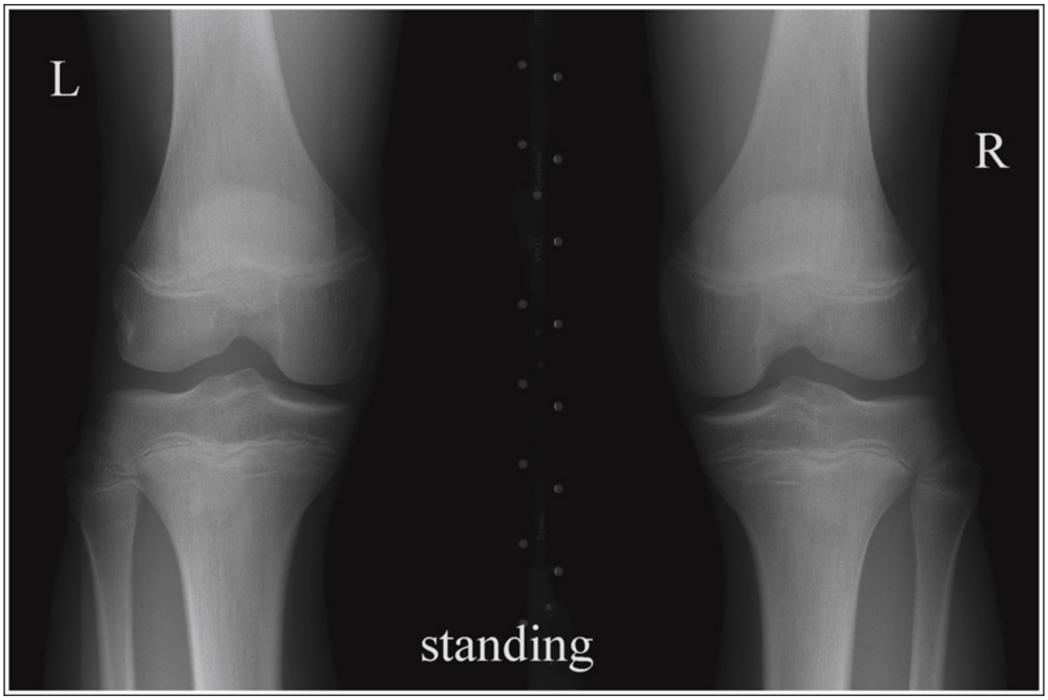


FIGURE 6.214 Bilateral weight-bearing flexed PA axial knee with excessive lower leg tilt with IR.

PA Axial Knee Analysis Practice

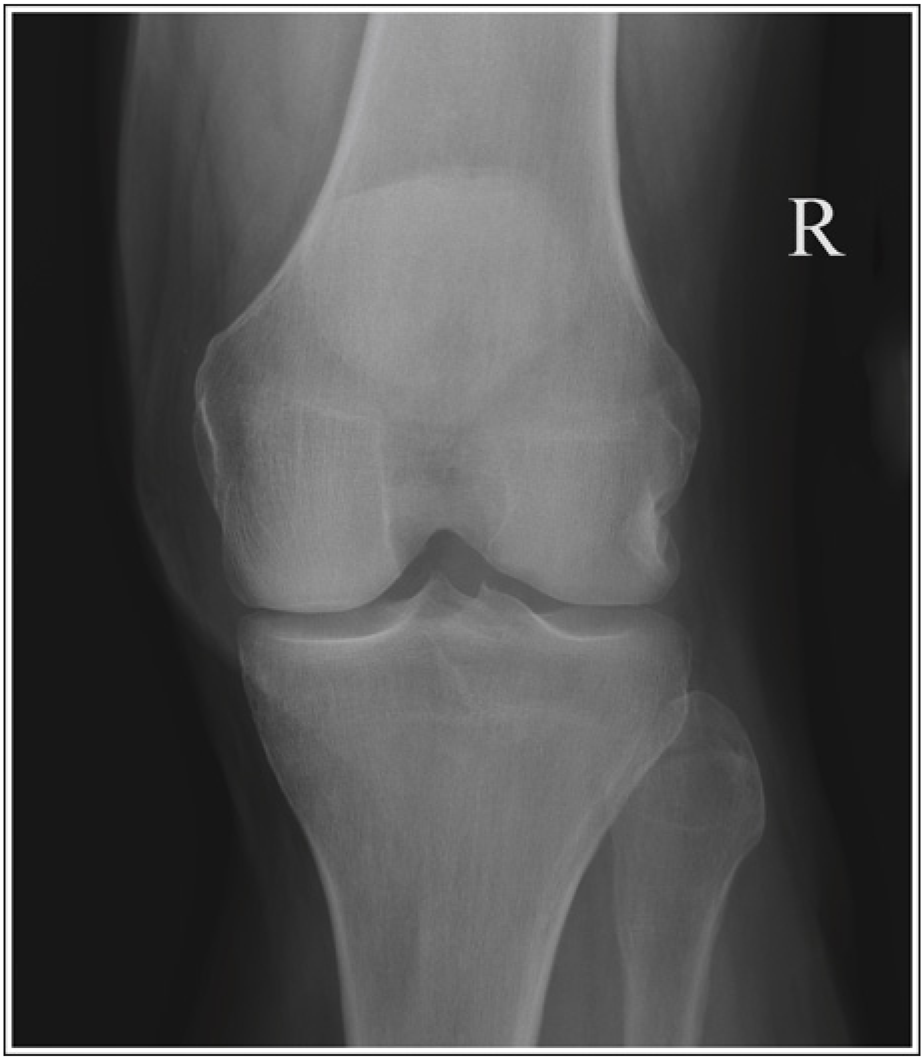


IMAGE 6.36

HOLMBLAD METHOD.

Analysis

The anterior and posterior cortical outlines of the proximal intercondylar fossa are demonstrated without superimposition and the patella is proximal to the intercondylar fossa. The degree of femur to IR angle was insufficient. The knee joint space is closed and the fibular head is more than 0.25 inch

(0.6 cm) from the tibial plateau. The distal lower leg was not adequately elevated.

Correction

Increase the degree of femur to IR angle until the femur is at a 60- to 70-degree angle with the IR and elevate the distal lower leg by resting the foot on the toes.

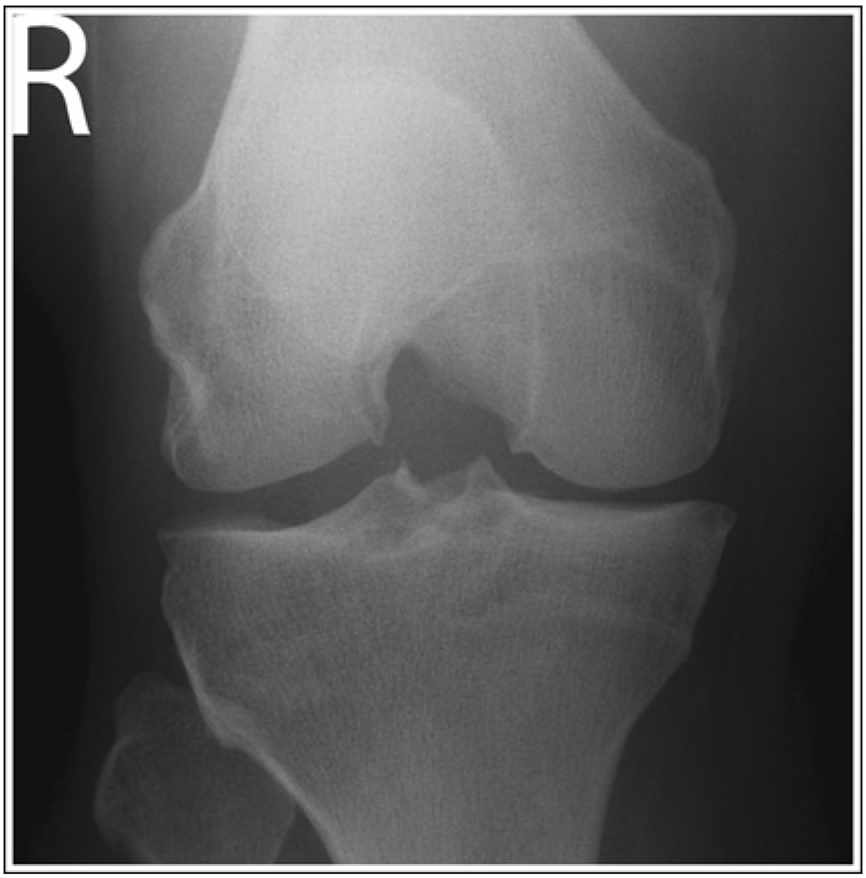


IMAGE 6.37

HOLMBLAD METHOD.

Analysis

The medial and lateral aspects of the intercondylar fossa are not superimposed, and the patella is situated laterally. Either the proximal femur was positioned vertically or the heel was rotated medially.

Correction

Position the proximal femur laterally, allowing the femur to incline naturally and/or align the long axis of the foot perpendicular to the imaging table.

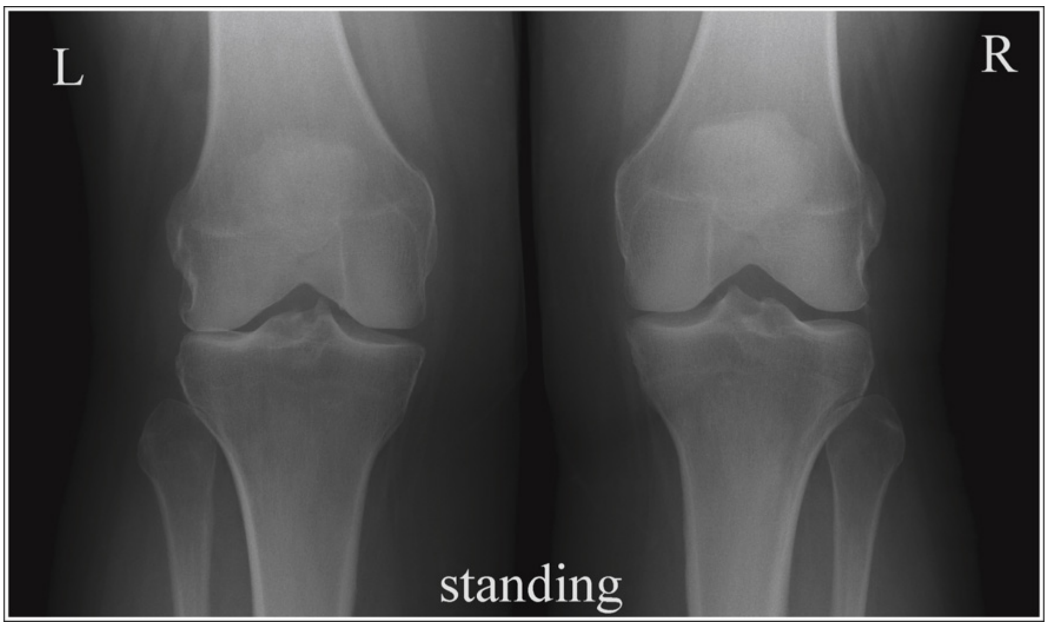


IMAGE 6.38

WEIGHT-BEARING BILATERAL PA FLEXED.

Analysis

The posterior cortical outlines of the proximal intercondylar fossa is demonstrated at a greater proximal distance than 0.25 (0.6 cm) from the anterior cortical outlines. The femur to IR angle was insufficient. The knee joint spaces are closed and the fibular heads are at a greater than 0.25 inch (0.6 cm) distance from the tibial plateaus. The lower legs to IR tilt was insufficient.

Correction

Increase the degree of femur to IR angle until the femurs are at a 45-degree angle with the IR and position the feet at a greater distance from the IR so the distal lower legs will be at a greater distance from the IR when they are tilted to place the knees against the IR.

Intercondylar Fossa: AP Axial Projection (Béclère Method)

See **Table 6.19** and **Figs. 6.215** and **6.216**.

TABLE 6.19

CR, Central ray; *IR*, image receptor.

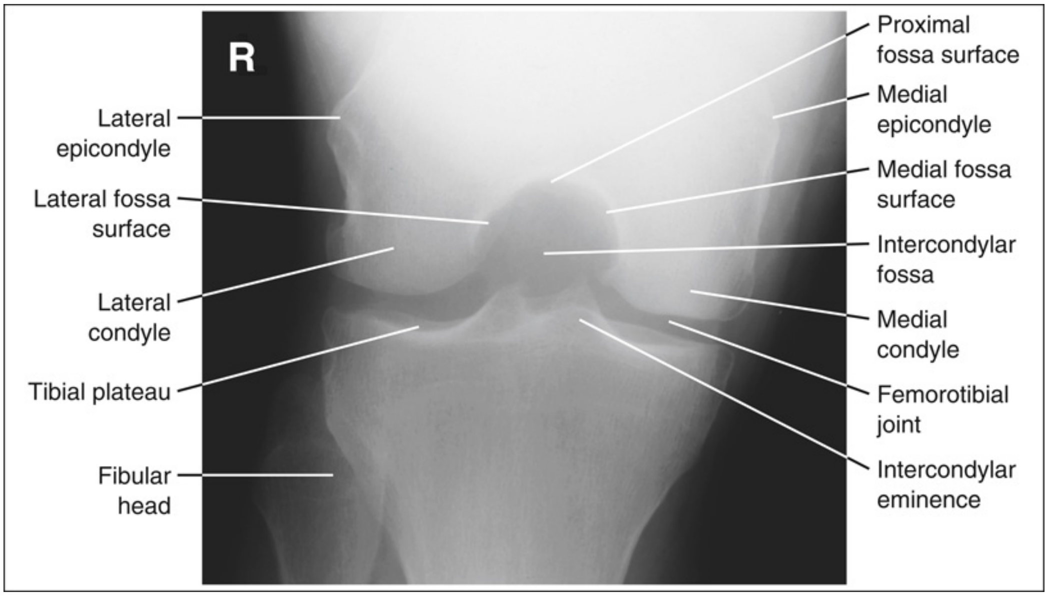


FIGURE 6.215 AP axial knee projection (Béclère method) with accurate positioning.

FIGURE 6.216 Proper patient positioning for AP axial knee projection (Béclère method).

Leg Positioning to Demonstrate the Proximal Intercondylar Fossa Surface

The proximal surface of the intercondylar fossa is placed in profile when the CR is aligned parallel with it. This is accomplished on an AP axial projection when the long axis of the femur is placed at a 60-degree angle with the IR and the CR is correctly angled and centered to the fossa (see **Fig. 6.216**). With a set CR, poor alignment of the proximal surface of the fossa occurs when the femoral shaft is angled more or less than 60 degrees with the IR, which also causes the knee to be flexed more or less than 45 degrees, and alters the placement of the patella on the femur as previously described.

Excessive Femoral Tilt With the IR

If the proximal surface of the intercondylar fossa is not in profile and the patellar apex is demonstrated within the intercondylar fossa on an AP axial knee projection, the femoral shaft was aligned more than 60 degrees with the IR (**Fig. 6.217**).

Insufficient Femoral Tilt With the IR

If the proximal surface of the intercondylar fossa is not in profile and the patellar apex is seen proximal to the intercondylar fossa on an AP axial knee projection, the long axis of the femur was aligned less than 60 degrees with the IR (**Fig. 6.218**).

CR Too Cephalically Angled: Closed Knee Joint Space

If an AP axial projection demonstrates a closed or narrowed knee joint space, the tibial plateau, and the fibular head demonstrated more than 0.5 inch (1.25 cm) distal to the tibial plateau, the distal lower leg was elevated too high or the CR was too cephalically angled (**Fig. 6.219**).

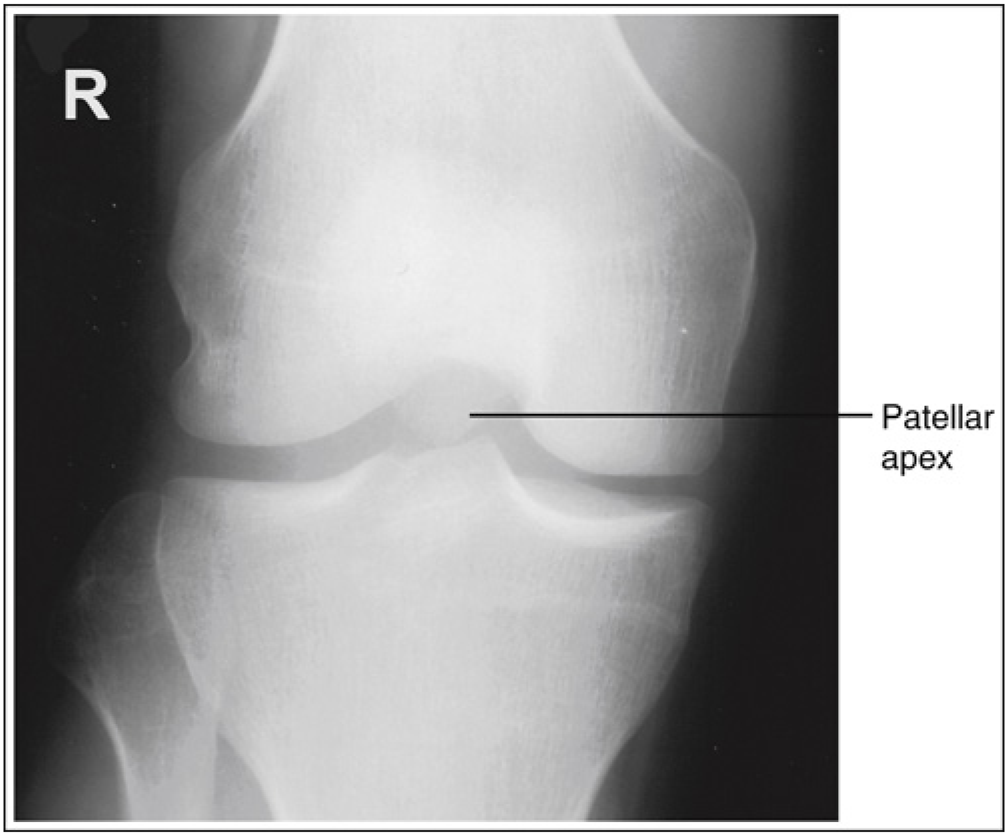


FIGURE 6.217 AP axial knee projection (Béclère method) taken with excessive knee flexion.

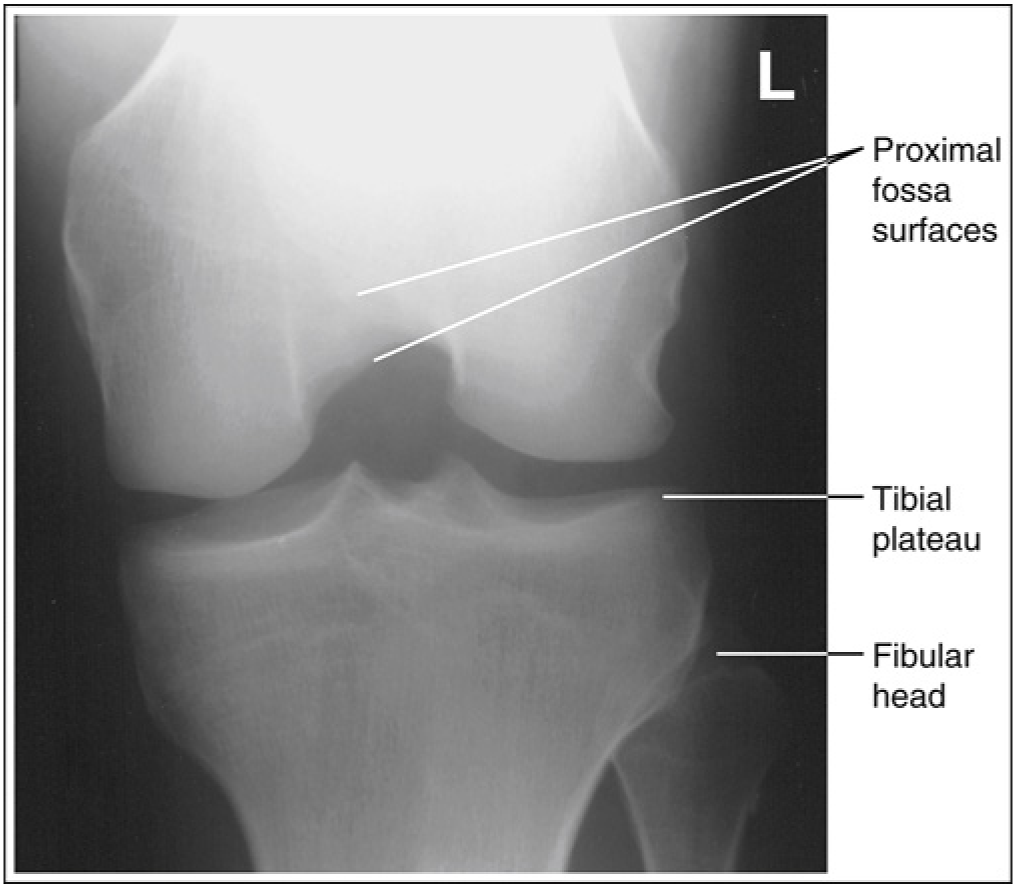


FIGURE 6.218 AP axial knee projection (Béclère method) taken with insufficient knee flexion.

CR Too Caudally Angled: Closed Knee Joint Space

If an AP axial projection demonstrates a closed or narrowed knee joint space, the tibial plateau, and fibular head demonstrated less than 0.5 inch (1.25 cm) distal to the tibial plateau, the distal lower leg was too depressed or the CR was too caudally angled (**Fig. 6.220**).

External Knee Rotation

When an AP axial knee is obtained that does not demonstrate the lateral and the medial surfaces of the intercondylar fossa in profile, the medial femoral condyle appears larger than the lateral condyle, and the tibia superimposes

more than one-half of the fibular head, the knee was externally rotated (**Fig. 6.221**).

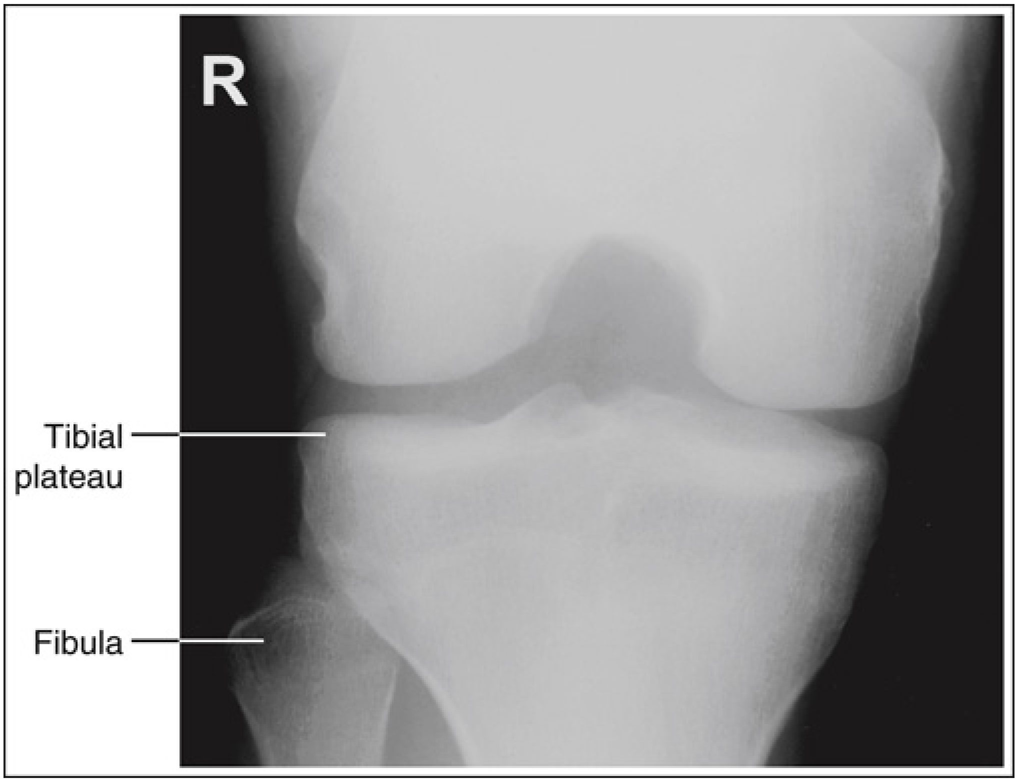


FIGURE 6.219 AP axial knee projection taken with the distal lower leg elevated or the CR angled too cephalically.

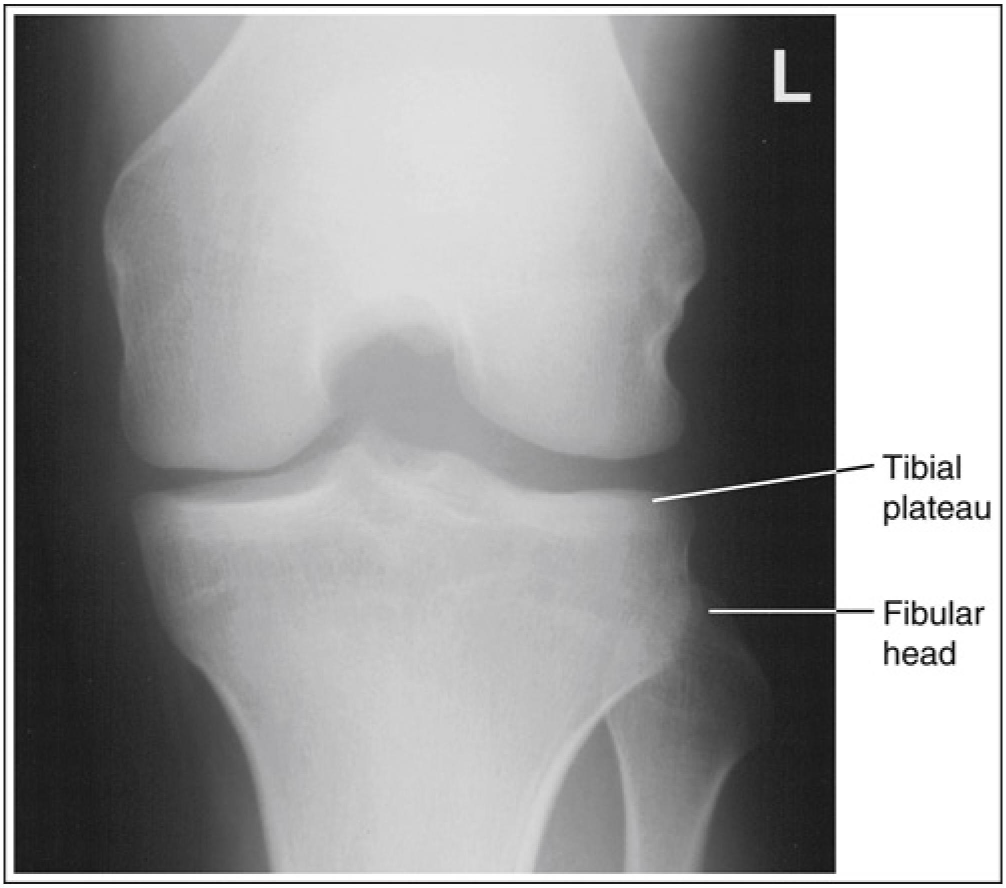


FIGURE 6.220 AP axial knee projection (Béclère method) taken with the distal lower leg depressed or the CR angled too caudally.

Internal Knee Rotation

When an AP axial knee is obtained that does not demonstrate the lateral and the medial surfaces of the intercondylar fossa in profile, the lateral femoral condyle appears larger than the medial condyle, and the tibia superimposes less than one-half of the fibular head, the knee was too internally rotated (**Fig. 6.222**).

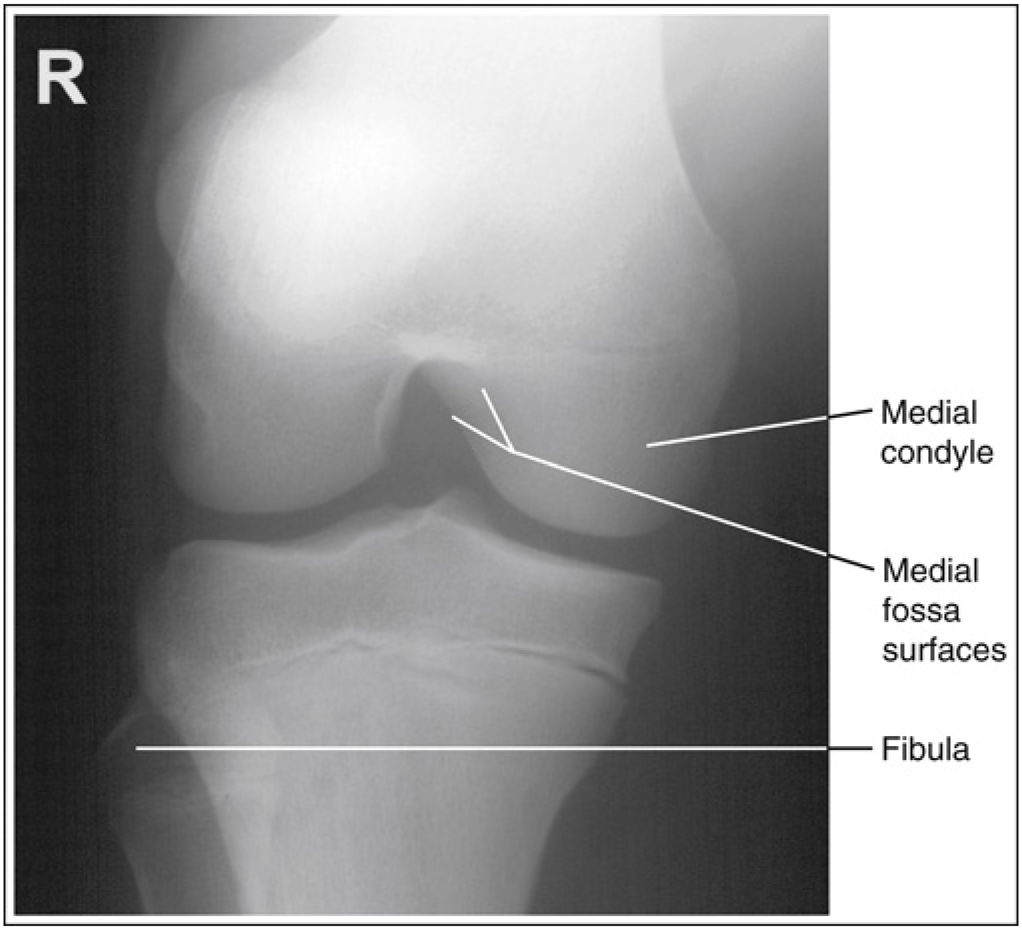


FIGURE 6.221 AP axial knee projection (Béclère method) taken with the knee externally rotated.

FIGURE 6.222 AP axial knee projection (Béclère method) taken with the knee internally rotated and CR angled too cephalically.

Patella and Patellofemoral Joint: Tangential Projection (Merchant Method)

See **Table 6.20** and **Figs. 6.223** and **6.224**.

Total Knee Replacement

Pre- and postoperative TKR tangential projections are often obtained to demonstrate patellar subluxation (**Fig. 6.225**). The TKR tangential knee projection should meet all the requirements listed in **Table 6.20**.

Axial Viewer

The AP axial patella projection uses an axial viewer knee-supporting device, as shown in **Fig. 6.224**. This freestanding device maintains the knees at a set degree of flexion, provides straps that restrain the legs, and contains an IR holder that keeps the IR at the proper angle with the CR. The angle of the CR and the angle placed on the axial viewer determines what aspect of the femurs' anterior surface will be visualized and how well the patellofemoral joint space is demonstrated. Although 45 degrees is the standard axial viewer angle used, the axial viewer is capable of supporting the knee flexion at 30-, 60-, or 75-degree angles as well. Each of these angles requires a predetermined CR angulation if an open patellofemoral joint is to be obtained. The easiest way to determine the CR angle to use for the different axial viewer angles is to know that the sum of the CR angle and the axial viewer's angle must equal 105 degrees. For example, if the axial viewer is set at 30 degrees, the CR angulation must be set at 75 degrees (30 + 75 = 105).

Fig. 6.226 demonstrates a series of lateral knee projections obtained with different degrees of knee flexion to demonstrate the locational change in the position of the patella in reference to the femur as the knee is flexed. Note that with increased knee flexion the patella moves distally onto the femoral patellar surface and then in the intercondylar sulcus. These projections also show how the degree of CR angulation would need to be decreased (made closer to perpendicular) as knee flexion increases to obtain an open patellofemoral joint space.

External Leg Rotation

An accurately positioned AP axial projection demonstrates the lateral femoral condyles with more height than the medial condyles because the

lateral condyles are situated more anterior to the medial condyles as discussed in the lateral knee above. If the legs are not internally rotated enough to place the femoral epicondyles parallel with the imaging table, the patellae are situated laterally, and either the anterior femoral condyles demonstrate equal height or the medial condyles demonstrate greater height than the lateral condyles (**Figs. 6.227** and **6.228**).

Patellar Subluxation

Because this projection is taken to demonstrate subluxation of the patella, the position of the patellae above the intercondylar sulci on an AP axial projection may vary. In a normal knee, the patella is directly above the intercondylar sulcus on an AP axial projection, as shown in **Fig. 6.223**. With patellar subluxation, the patella is lateral to the intercondylar sulcus, as shown in **Fig. 6.229**. Do not mistake a subluxed patella for knee rotation. Although both conditions result in a laterally positioned patella, the rotated knee demonstrates the femoral condyle at the same height or with the medial condyle at a higher level than the lateral condyle, and the nonrotated knee that demonstrates a subluxed patella will demonstrate the lateral condyle higher than the medial condyle.

To demonstrate patellar subluxation, the quadriceps femoris (four muscles that surround the femoral bone) must be in a relaxed position. This is accomplished by instructing the patient to relax the leg muscles, allowing the calf straps to maintain the internal leg rotation. If the patient does not relax the quadriceps muscles, a patella that would be subluxed on relaxation of the muscles may appear normal.

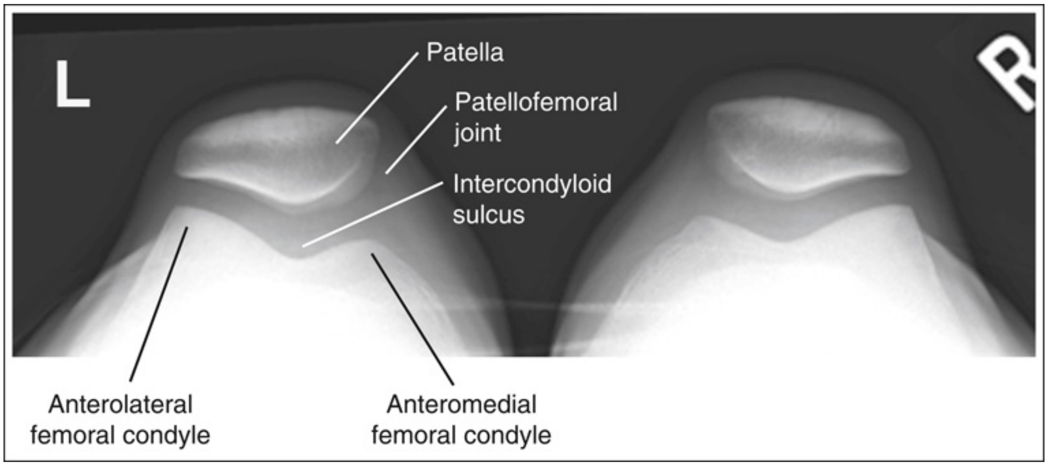


FIGURE 6.223 Tangential patellae projection (Merchant method) with accurate positioning.

FIGURE 6.224 Proper patient positioning for tangential patellae projection (Merchant method).

FIGURE 6.225 Accurately positioned tangential patellae projection (Merchant method) on patient with TKR.

FIGURE 6.226 Lateral knee projections obtained with varying degrees of knee flexion to demonstrate the changing position of the patella.

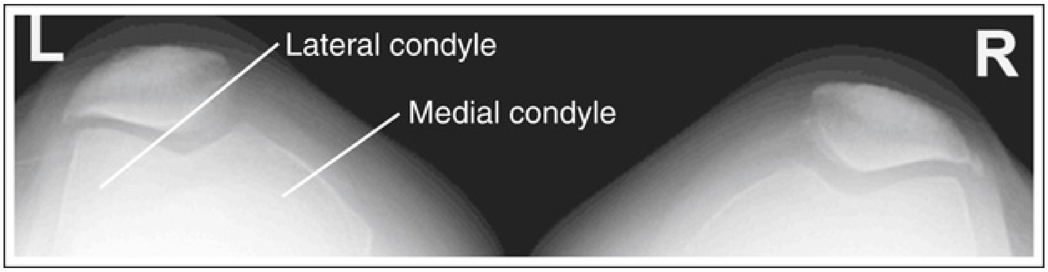


FIGURE 6.227 Tangential patellae projection (Merchant method) taken without internal leg rotation.

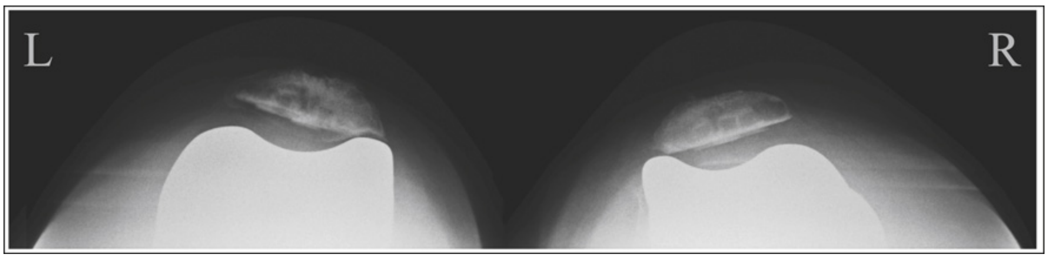


FIGURE 6.228 Tangential patellae projection (Merchant method) taken without internal leg rotation on patient with TKR.

FIGURE 6.229 Tangential patellae projection (Merchant method) of a patient with patellar subluxation.

TABLE 6.20

CR, Central ray; *IR*, image receptor.

Femurs Parallel With Imaging Tabletop: Anterior Thigh Soft Tissue in Patellofemoral Joint Space

The relationship of the femurs to the imaging table determines how much of the anterior thigh is exposed and projected into the patellofemoral joint spaces on an AP axial patellae projection. It is when the femurs are placed parallel with the imaging tabletop that the least amount of anterior femoral soft tissue is projected into the patellofemoral joint spaces. Because the distal femurs are typically lower than the proximal femurs when the patient is supine (**Fig. 6.230**), the height of the axial viewer needs to be elevated or the imaging table lowered to bring the femoral shaft parallel with the imaging tabletop.

If the distal femurs are positioned closer to the imaging tabletop than the proximal femurs for an AP axial knee, the angled CR will traverse the anterior thigh soft tissue and project it into the patellofemoral joint space (**Fig. 6.231**). Although the patellofemoral joint space remains open on such a projection, the space is often underexposed.

Excessive Knee Flexion: Patellae in Patellofemoral Joint Spaces

The relationship of the posterior knee curves to the bend of the axial viewer determines whether the CR will be parallel with the patellofemoral joint spaces. To demonstrate open patellofemoral joint spaces, the posterior curves of the knees are positioned directly above the bend in the axial

viewer, as shown in **Fig. 6.232**. If the posterior curves of the knees are situated below this, flexing the knees more than 45 degrees, the projection will demonstrate a closed or narrowed patellofemoral joint space, and the posterior surface of the patellae or the patellae will rest against the intercondylar sulci (**Figs. 6.233** and **6.234**).

FIGURE 6.230 Poor femur positioning for a tangential patellae projection (Merchant method).

Insufficient Knee Flexion: Tibial Tuberosities in Patellofemoral Joint Space

If the posterior curves of the knees are situated too far above the bend of the axial viewer, extending the knee so it is flexed less than 45 degrees, the

tibial tuberosities are demonstrated within the patellofemoral joint space (**Figs. 6.235** and **6.236**).

Positioning for Large Calves

The tibial tuberosities may also be demonstrated within the patellofemoral joint spaces in a patient with thick calves, even when the posterior knee curves have been accurately positioned to the bend of the axial viewer. The thick calves cause the lower leg to be elevated from the viewer and the knee to be flexed less than that indicated on the axial viewer degree indicator and required for the projection. For such patients, the axial viewer's angulation should be decreased until the knees are flexed 45 degrees.

FIGURE 6.231 Tangential patellae projection (Merchant method) taken with the distal femurs depressed and without adequate internal leg rotation.

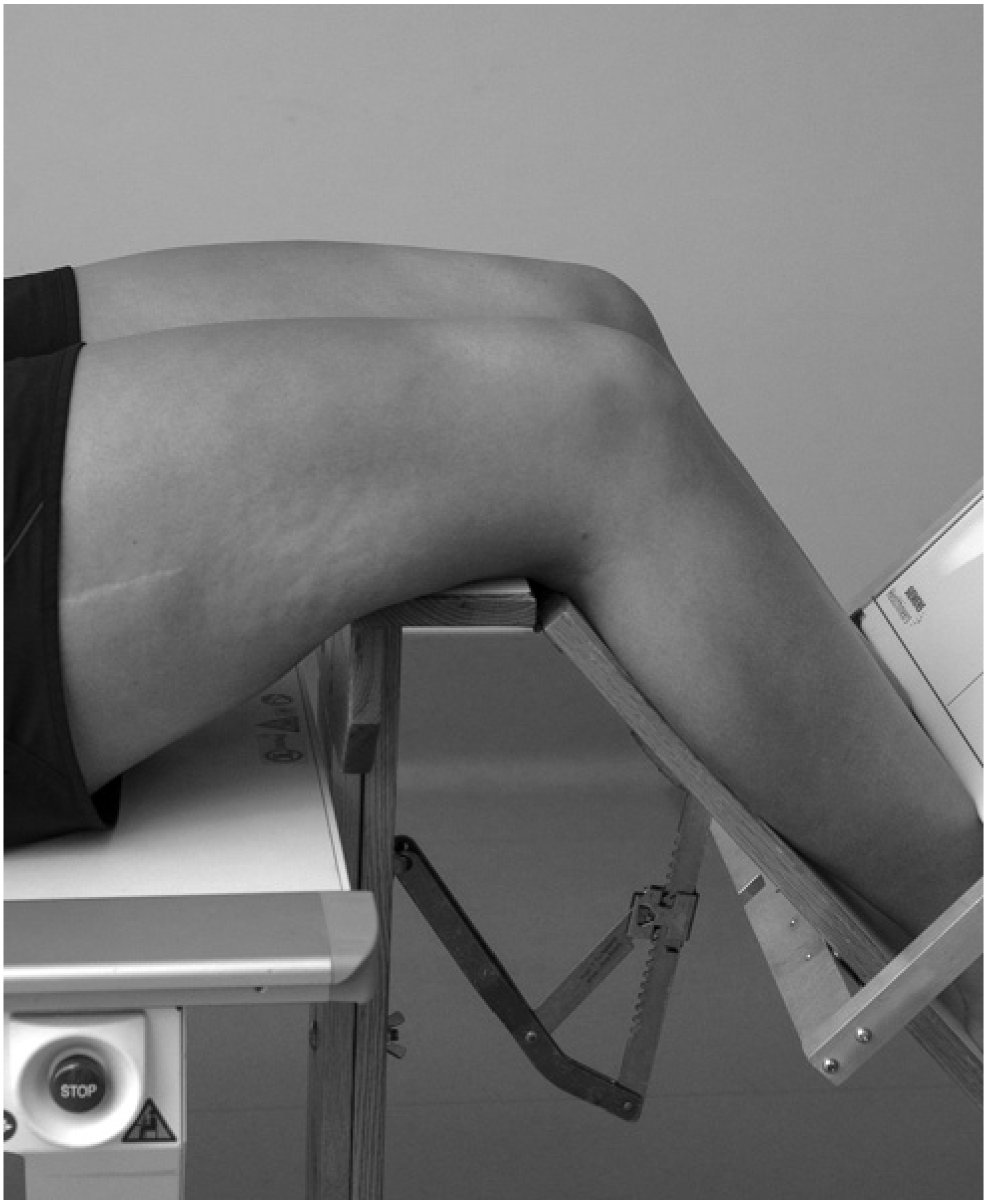


FIGURE 6.232 Proper posterior knee and axial viewer positioning for the tangential patellae projection (Merchant method).

FIGURE 6.233 Posterior knee curve situated below bend in axial viewer for the tangential patellae projection (Merchant method). Knees flexed more than 45 degrees.

Light Field Silhouette Indicates Accurate Positioning

Evaluate the silhouette of the knees that is created on the IR when the collimation light is on before exposing the IR. When the legs have been accurately positioned, these silhouettes will display oval shadows with indentations on each side that outline the patellae (**Fig. 6.237**).

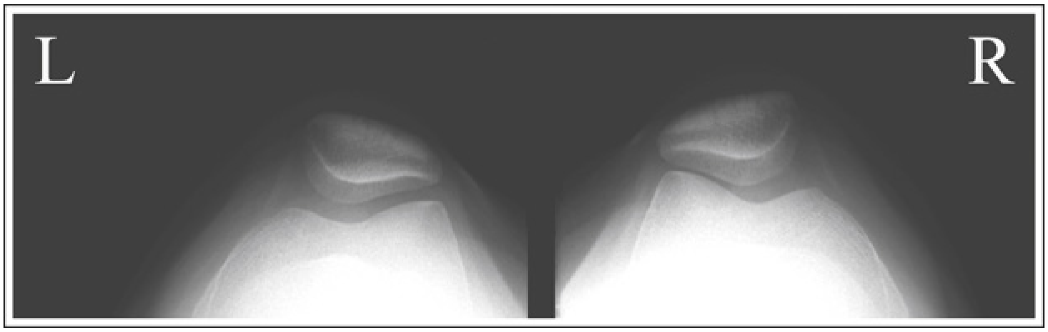


FIGURE 6.234 Tangential patella projection (Merchant method) taken with the knees flexed more than the degree that is set on the axial viewer.

FIGURE 6.235 Posterior knee curve situated above bend in axial viewer for the tangential patellae projection (Merchant method). Knees flexed less than 45 degrees.

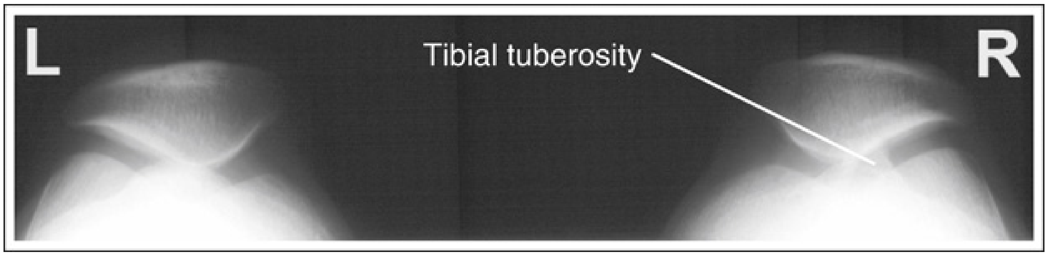


FIGURE 6.236 Tangential patellae projection (Merchant method) taken with the knees extended more than the degree that is set on the axial viewer.

FIGURE 6.237 Proper knee silhouettes and CR centering for tangential patellae projection (Merchant method).

Tangential (Merchant) Patella Analysis Practice

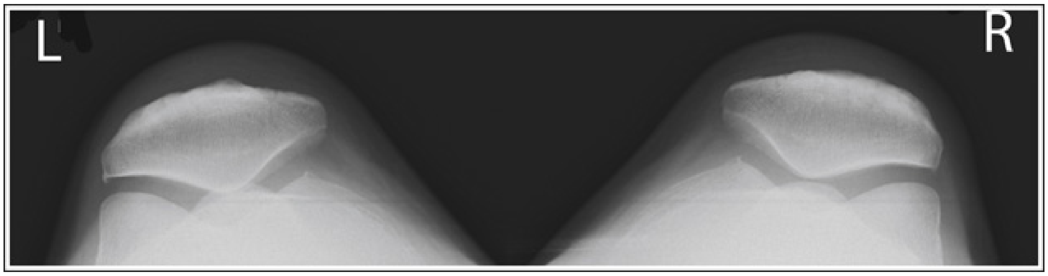


IMAGE 6.39

Analysis

The tibial tuberosities are demonstrated within the patellofemoral joint spaces. The posterior knee curve was positioned too far above the axial viewer's bend. The patellae are demonstrated directly above the intercondylar sulci and are rotated laterally. The medial femoral condyles demonstrate more height than the lateral condyles. The legs were externally rotated.

Correction

Slide the knees toward the axial viewer until the posterior knee curvature is just superior to the bend on the viewer and internally rotate the legs until the patellae are situated superiorly.

IMAGE 6.40

Analysis

The patellae are resting against the intercondylar sulci, obscuring the patellofemoral joint spaces. The posterior knee curve is positioned at or below the bend on the axial viewer. The femoral condyles are close to equal in height. The legs were not internally rotated.

Correction

Slide the knees away from the axial viewer until the posterior knee curvature is just superior to the bend of the viewer. Internally rotate the legs until the femoral epicondyles are aligned parallel with the imaging tabletop.

Patella and Patellofemoral Joint: Tangential Projection (Inferosuperior and Settegast Method)

See **Table 6.21** and Figs. **6.238**–**6.241**.

Knee Flexion and CR Angulation

When the hip and foot are on the same horizontal surface as they are when sitting on the imaging table and the knee is flexed for a tangential patella, the degree of proximal CR angulation that is required parallel to the patellofemoral joint space increases as the degree of knee flexion increases.

Fig. 6.242 demonstrates lateral knee projections that are flexed 45 and 90 degrees to show the change in patella location, the aspect of the femoral condyles that are positioned in profile, and how the CR needs to be increased to demonstrate an open patellofemoral joint space with the different degrees of knee flexion for the tangential patella projection. The inferosuperior projection (45-degree knee flexion) places the anterior aspect of the femoral condyles in profile, as demonstrated by the lateral condyle demonstrating more height than the medial condyle, and the Settegast method (90-degree knee flexion) places the distal aspect of the femoral condyles in profile, as demonstrated by both femoral condyles demonstrating equal height.

Inferosuperior: Knee Flexion

With accurate knee flexion, the CR angulation used will determine if the anterior tibia is positioned 0.125 inch (0.3 cm) distal to the intercondylar sulcus and if the patellofemoral joint space will be open. When evaluating an inferosuperior tangential patella projection that demonstrates a closed patellofemoral joint space, first determine if the CR is traversing the correct aspect of the femur. If the lateral condyle demonstrates more height than the medial condyle, there is no problem with knee flexion and the CR needs to be adjusted, but if the inferosuperior tangential patella projection demonstrates the femoral condyles with equal height, the knee was flexed more than 45 degrees and needs to be adjusted (**Fig. 6.243**). If knee flexion is accurate and the projection demonstrates a closed patellofemoral joint space, evaluate the distance that the anterior tibia is distal from the intercondylar sulcus to determine if the CR angle needs to be increased or decreased.

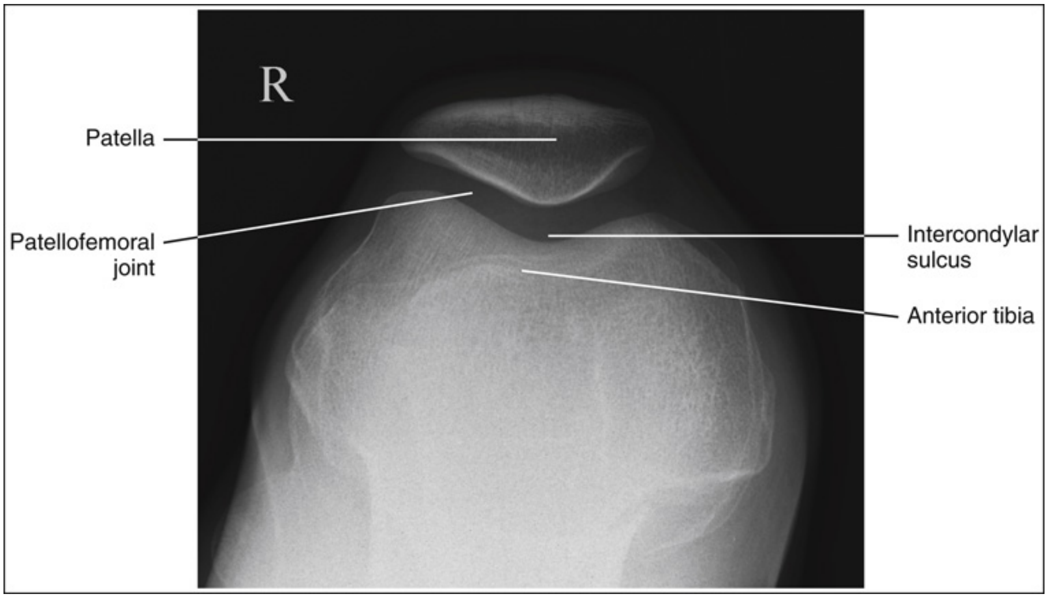


FIGURE 6.238 Accurately positioned tangential patella inferosuperior projection (45 degrees knee flexion).

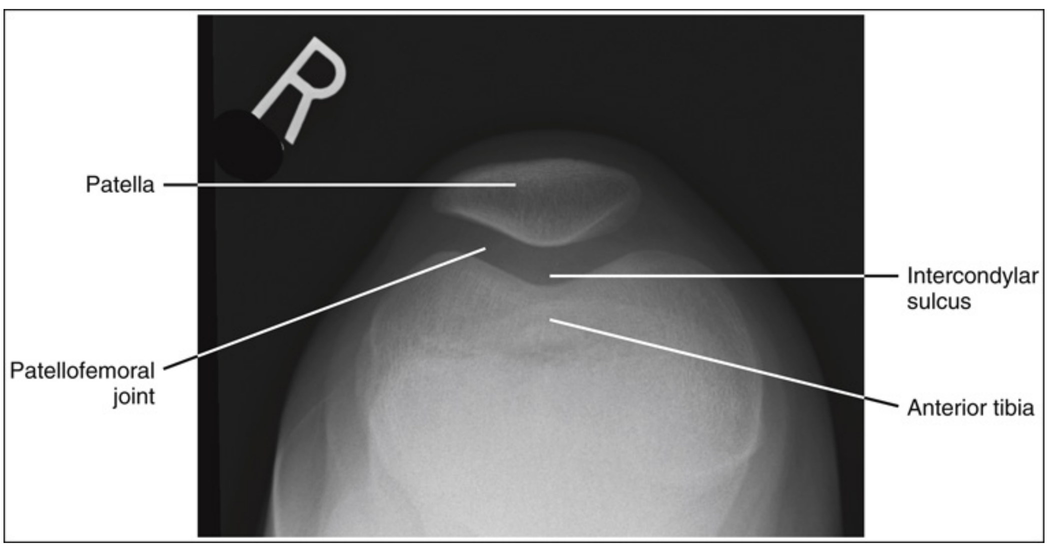


FIGURE 6.239 Accurately positioned tangential patella projection (Settegast method; 90-degree knee flexion).

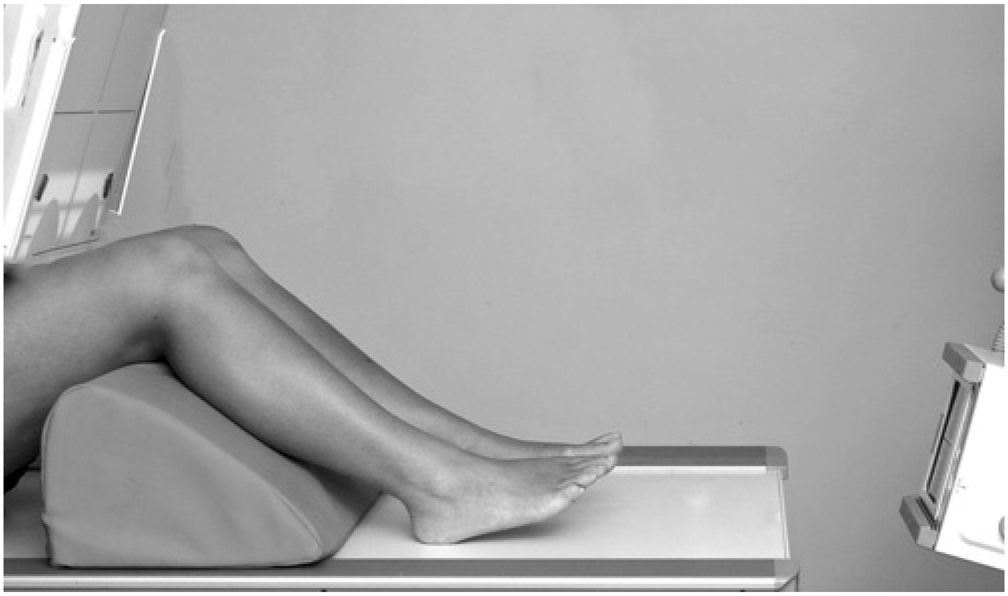


FIGURE 6.240 Proper patient positioning for the tangential patella projection (Inferosuperior; 45-degree knee flexion).

FIGURE 6.241 Proper patient positioning for the tangential patella projection (Settegast method; 90-degree knee flexion).

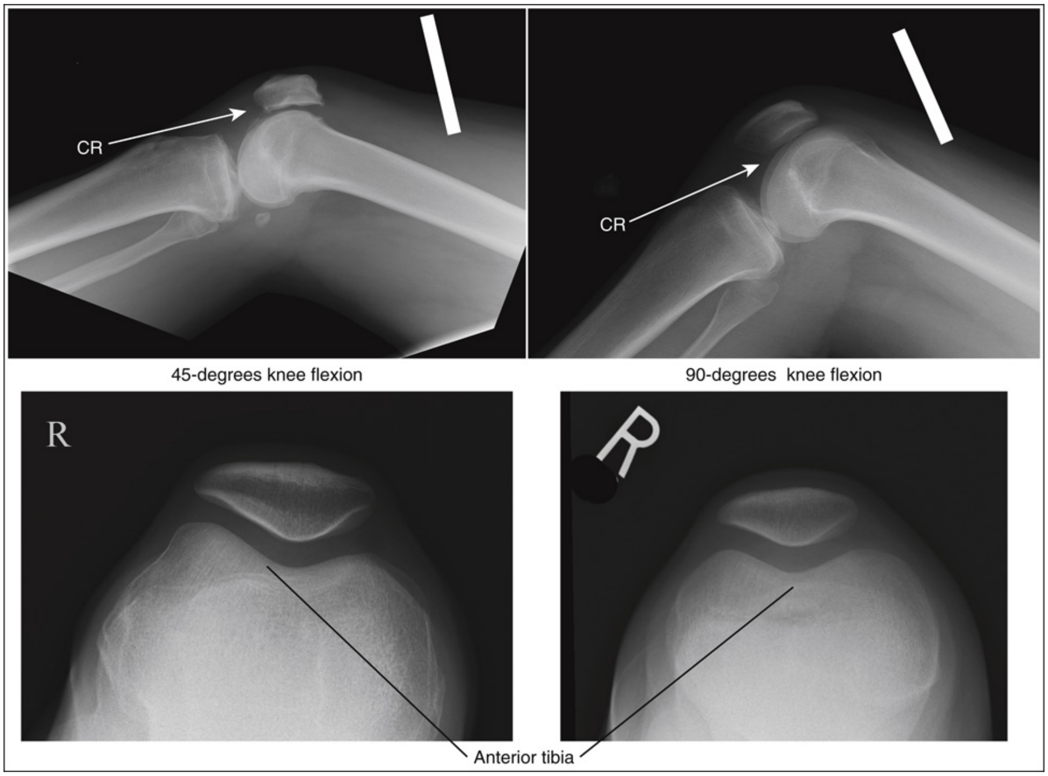


FIGURE 6.242 Lateral knee projections obtained with varying degrees of knee flexion to demonstrate the changing position of the patella and aspect of the femoral condyles that are in profile.

TABLE 6.21

CR, Central ray; *IR*, image receptor.

Inferosuperior: Insufficient/Excessive CR Angulation

If the 45-degree tangential patella projection demonstrates the lateral femoral condyle with more height than the medial femoral condyle and the

patellofemoral joint space is closed, evaluate the distance the anterior tibia is from the intercondylar sulcus to determine whether the CR angle needs to be increased or decreased. If the anterior tibia is farther than 0.125 inch (0.3 cm) distal to the intercondylar sulcus, the CR angle needs to be increased to parallel the patellofemoral joint space, and if the anterior tibia is closer or above the intercondylar sulcus, the CR angle needs to be decreased (**Fig. 6.244**).

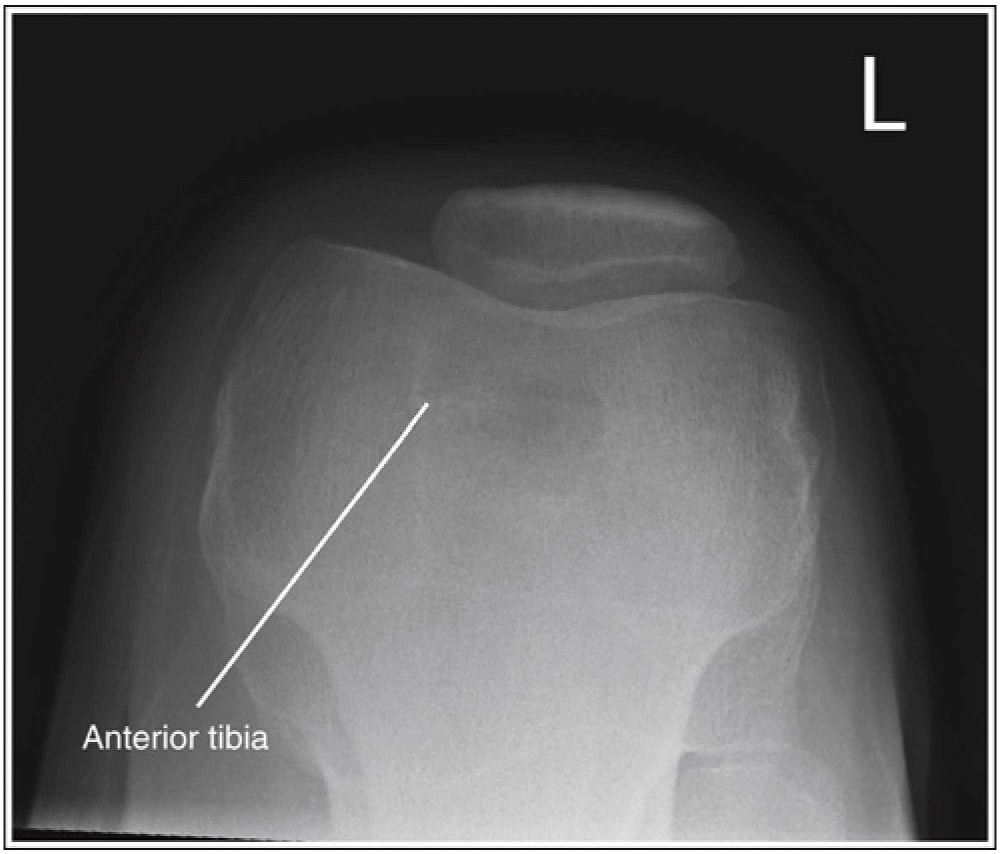


FIGURE 6.243 Tangential patella projection (inferosuperior) obtained with excessive knee flexion.

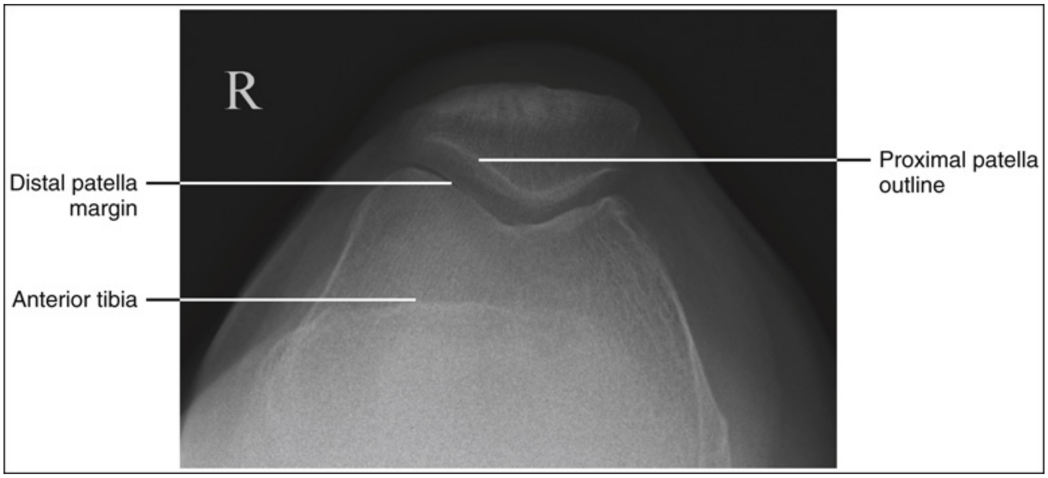


FIGURE 6.244 Tangential patella projection (inferosuperior) obtained with insufficient CR angulation.

Settegast Method: CR Angulation

If a Settegast method patella projection demonstrates the femoral condyles at the same height and the patella femoral joint space is closed, the knee was accurately flexed and the CR traversed the distal aspect of the femur. To determine how to adjust the CR angulation to open the patellofemoral joint space, evaluate the distance from the anterior tibia to the intercondylar sulcus. If this distance is farther than 0.125 inch (0.3 cm), the CR angulation was insufficient (**Fig. 6.245**), and if the distance is closer than 0.125 inch (0.3 cm) or the anterior tibia is seen above the intercondylar sulcus, the CR angulation was excessive (**Fig. 6.246**).

Misalignment of the Foot, Knee, and Hip

If the foot is placed laterally to the hip for a tangential patella, a portion of the proximal lower leg will not superimpose the distal femur but will be lateral to it, causing medial knee rotation and the patella to be rotated

laterally instead of being centered on the intercondylar sulcus on the resulting projection (**Fig. 6.247**).

IR Placement and Distortion

Aligning the IR perpendicular to the CR does result in a larger OID than will result if the IR is allowed to lay against the distal femur for the tangential patella projection, but failing to align the CR and IR perpendicular results in elongation distortion (**Figs. 6.248** and **6.249**).

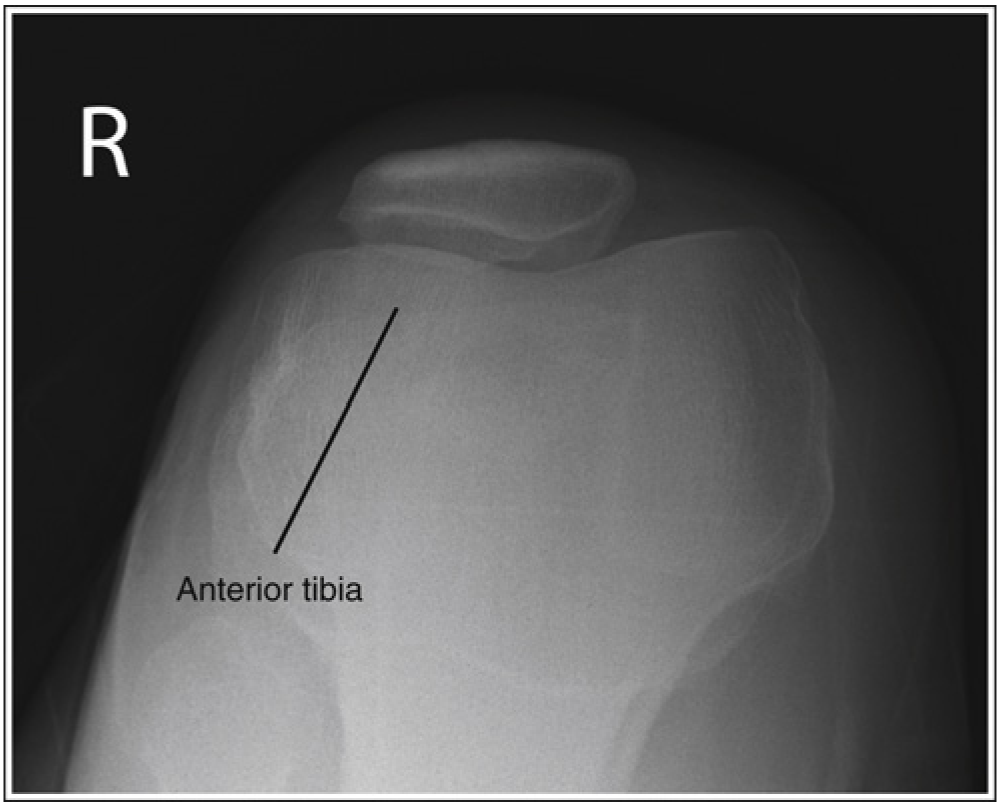


FIGURE 6.245 Tangential patella projection (Settegast method) taken with insufficient CR angulation.

FIGURE 6.246 Tangential patella projection (Settegast method) taken with excessive CR angulation.

FIGURE 6.247 Tangential patella projection (Settegast method) taken with the foot positioned laterally to the hip.

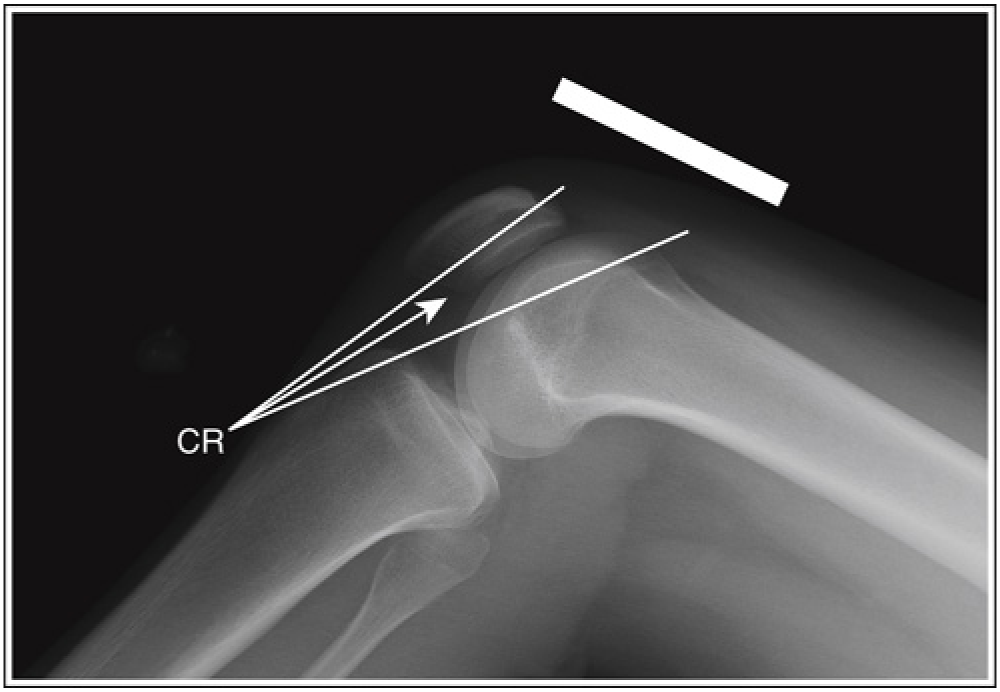


FIGURE 6.248 A lateral knee projection demonstrating the elongation distortion that results when the tangential patella projection (Settegast method) is obtained with the IR placed against the femur.

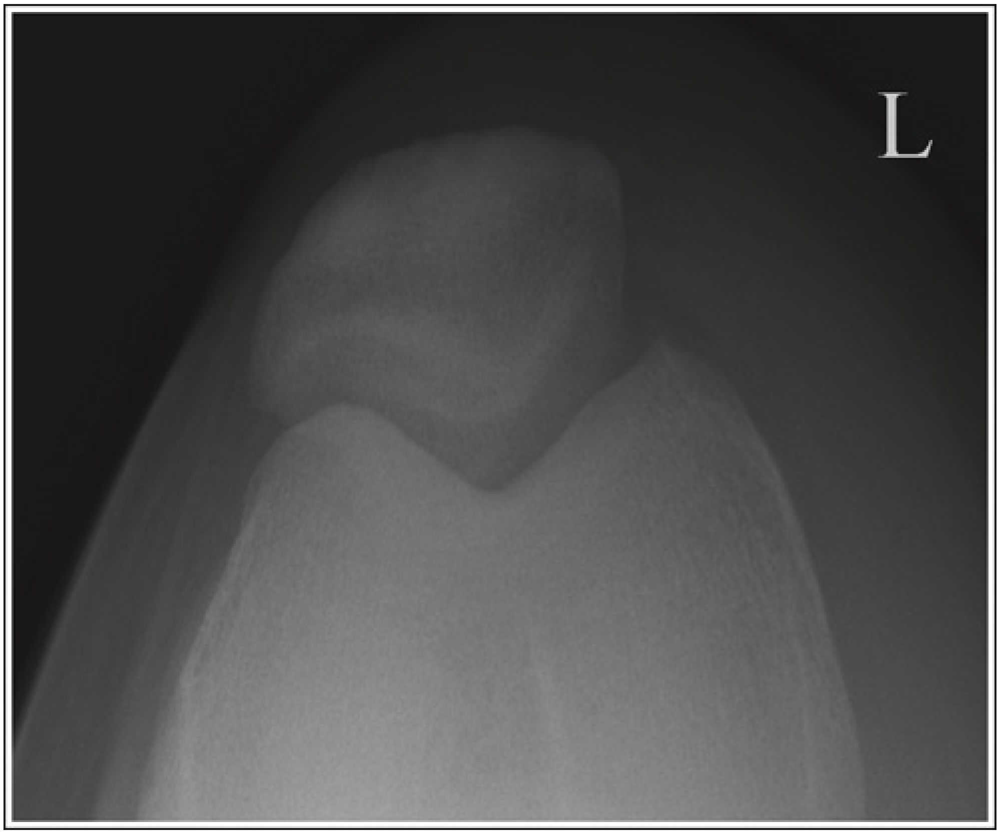


FIGURE 6.249 Tangential patella projection (Settegast method) obtained with the IR placed against the femur so it is not perpendicular with the CR.

Tangential (Inferosuperior and Settegast) Patella Analysis Practice

IMAGE 6.41

SETTEGAST METHOD.

Analysis

The femoral condyles are at the same height, indicating that the knee was accurately flexed to 90 degrees. The patellofemoral joint space is closed, and the anterior tibia is more than 0.125 inch (0.3 cm) from the intercondylar sulcus. The CR was angled too caudally. A portion of the proximal lower leg is lateral to the distal femur, and the patella is rotated laterally. The foot was positioned lateral to the hip.

Correction

Increase the CR angulation to parallel the patellofemoral joint space. Place the foot more medially, aligning it with the hip.

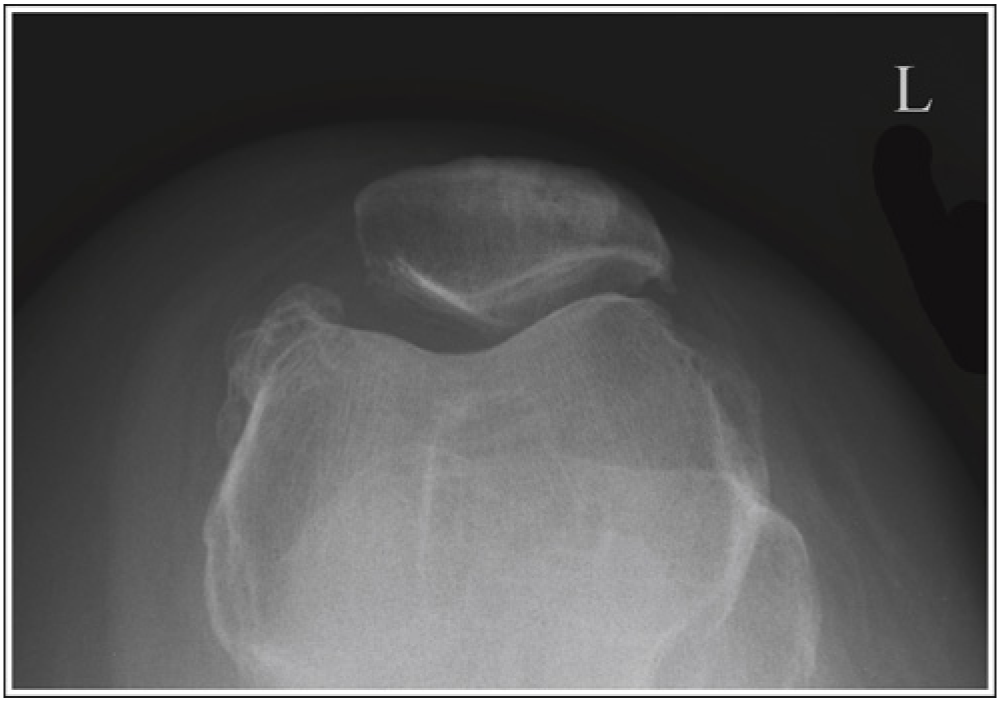


IMAGE 6.42

TANGENTIAL PATELLA (INFEROSUPERIOR) PROJECTION.

Analysis

The femoral condyles are at about the same height, indicating that the CR traversed the distal aspects of the condyles instead of the anterior aspects. The patellofemoral joint space is closed, and the anterior tibia is at a distance that is greater than 0.125 inch (0.3 cm) distal from the intercondylar sulcus; because the correct aspect of the condyles is not in profile when the knee is extended to 45 degrees, these two issues will also be solved. A portion of the proximal lower leg is lateral to the distal femur, and the patella is rotated laterally. The foot was positioned lateral to the hip.

Correction

Decrease the knee flexion to 45 degrees, realign the CR to a lower leg angle as needed to parallel the patellofemoral joint space, and align the foot with the hip.

IMAGE 6.43

SETTEGAST METHOD.

Analysis

The femoral condyles are at the same height, indicating the CR accurately traversed the distal femoral condyles. The patellofemoral joint space is closed, and the anterior tibia is at a distance that is greater than 0.125 inch (0.3 cm) from the intercondylar sulcus. The CR was angled too caudally.

Correction

Increase the CR angulation to parallel the patellofemoral joint space.

Femur: AP Projection

Distal Femur

See **Table 6.22** and **Figs. 6.250** and **6.251**.

External Leg Rotation

If the leg was externally rotated for an AP distal femur projection, the femoral epicondyles are not in profile, the medial femoral condyle appears larger than the lateral femoral condyle, and the tibia superimposes more than one-half of the fibular head (**Fig. 6.252**).

Internal Leg Rotation

If the leg was too internally rotated for an AP distal femur projection, the femoral epicondyles are not demonstrated in profile, the lateral femoral condyle appears larger than the medial condyle, and the tibia superimposes less than one-half of the fibular head (**Fig. 6.253**).

Positioning for Fracture: Leg Rotation

When a fractured femur is in question, the leg should not be internally rotated, but left as is unless indicated by your facility. Because the leg is not internally rotated when a fracture is in question, the AP trauma distal femur commonly demonstrates external rotation unless the CR is angled to align it perpendicular to the femoral epicondyles (**Fig. 6.254**).

Femoral Shaft Overlap of Distal and Proximal Projections

Because the IR is not long enough to include the entire femur on one projection, to evaluate the entire femur, it is necessary to take two separate projections—one of the distal and one of the proximal femur. These projections should demonstrate at least 2 inches (5 cm) of femoral shaft overlap so the evaluator is certain that all of the femoral shaft has been demonstrated. To prevent greater than a 2-inch (5 cm) femoral shaft overlap and provide appropriate radiation protection, one of the projections is collimated to a smaller size. When choosing whether the proximal or distal femur should be obtained with the larger field size, make certain that the overlapped area is not located at the section of femur where a fracture or disease process is demonstrated (**Fig. 6.255**).

TABLE 6.22

AP, Anteroposterior; *CR*, Central ray; *IR*, image receptor.

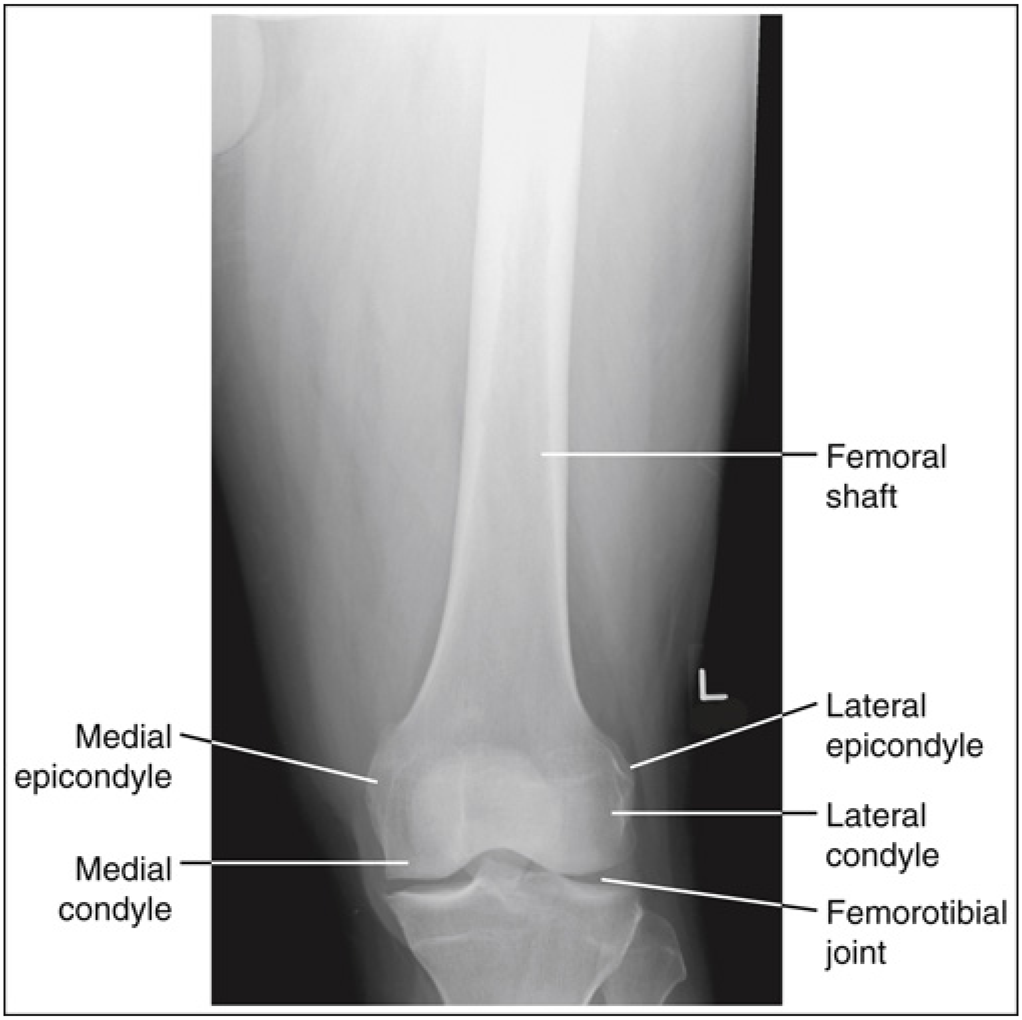


FIGURE 6.250 AP distal femur projection with accurate positioning.

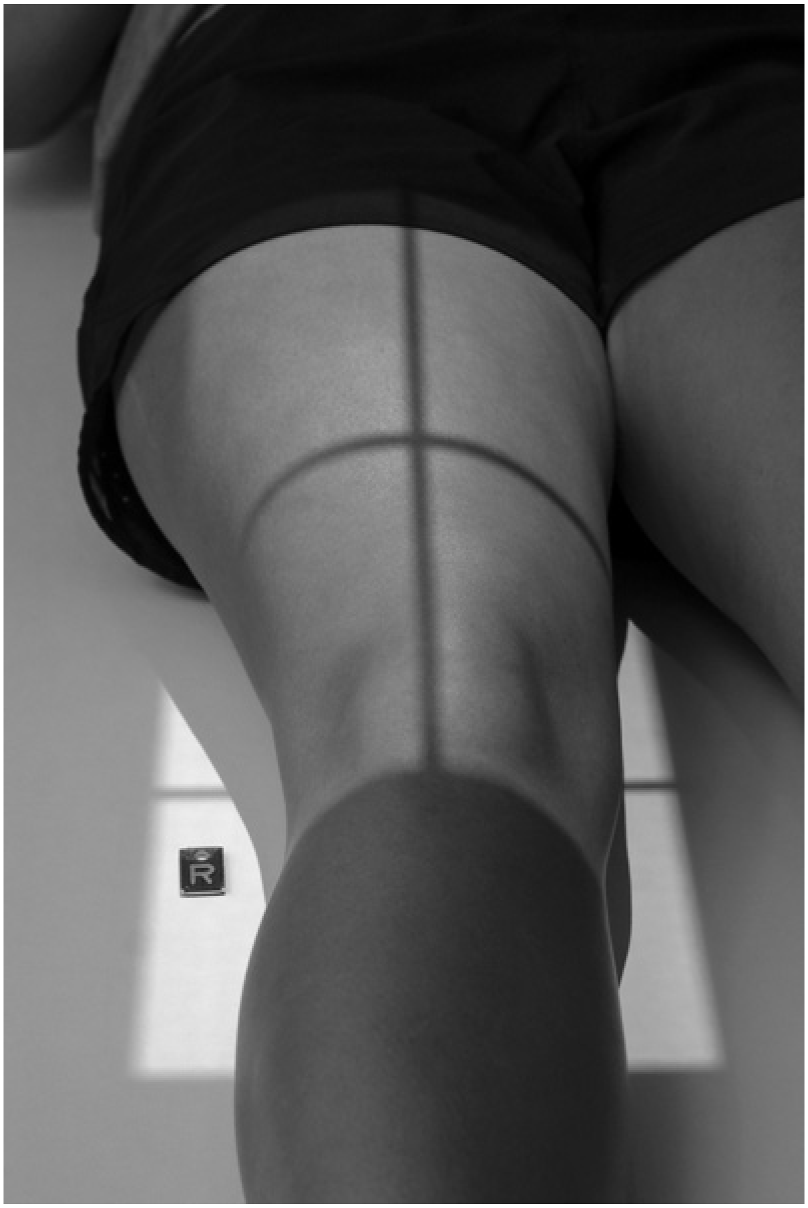


FIGURE 6.251 Proper patient positioning for AP distal femur projection.

FIGURE 6.252 AP distal femur projection taken with external rotation.

FIGURE 6.253 AP distal femur projection taken with internal rotation.

See Table 6.23 and Figs. 6.256 and 6.257.

FIGURE 6.254 AP fractured distal femur projection obtained with external rotation of hip and internal rotation of the lower leg.

Proximal Femur

See **Table 6.23** and **Figs. 6.256** and **6.257**.

Pelvis Rotation: Toward Affected Femur

If the pelvis has been rotated toward the affected femur, the ischial spine is demonstrated without pelvic brim superimposition and visualization of the obturator foramen is decreased (**Fig. 6.258**).

Pelvis Rotation: Away From Affected Femur

If the pelvis has been rotated away from the affected femur, the ischial spine is not aligned with the pelvic brim but is demonstrated closer to the acetabulum, and demonstration of the obturator foramen is increased (**Fig. 6.259**).

External Leg Rotation

On external leg rotation, the femoral neck inclines posteriorly and is foreshortened on an AP femoral projection. Increased external rotation increases the degree of posterior decline and foreshortening of the femoral neck on the projection. If the leg is externally rotated enough to position the foot at a 45-degree angle with the IR, which positions the femoral epicondyles at a 60- to 65-degree angle with the IR, the femoral neck declines posteriorly enough to nearly position it on end, demonstrating maximum femoral neck foreshortening and the lesser trochanter in profile (**Fig. 6.260**).

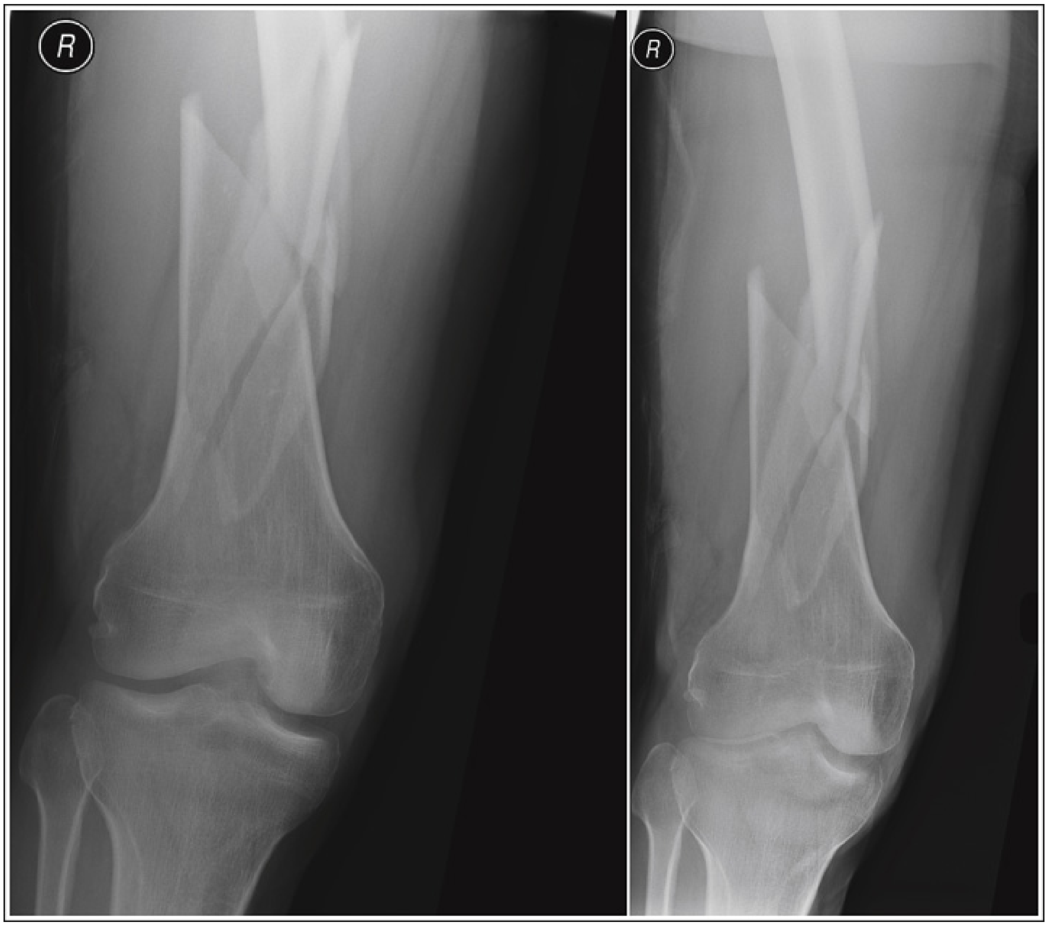


FIGURE 6.255 AP distal femur projections demonstrating how it is best to keep the collimation open to include the entire fracture site on one projection.

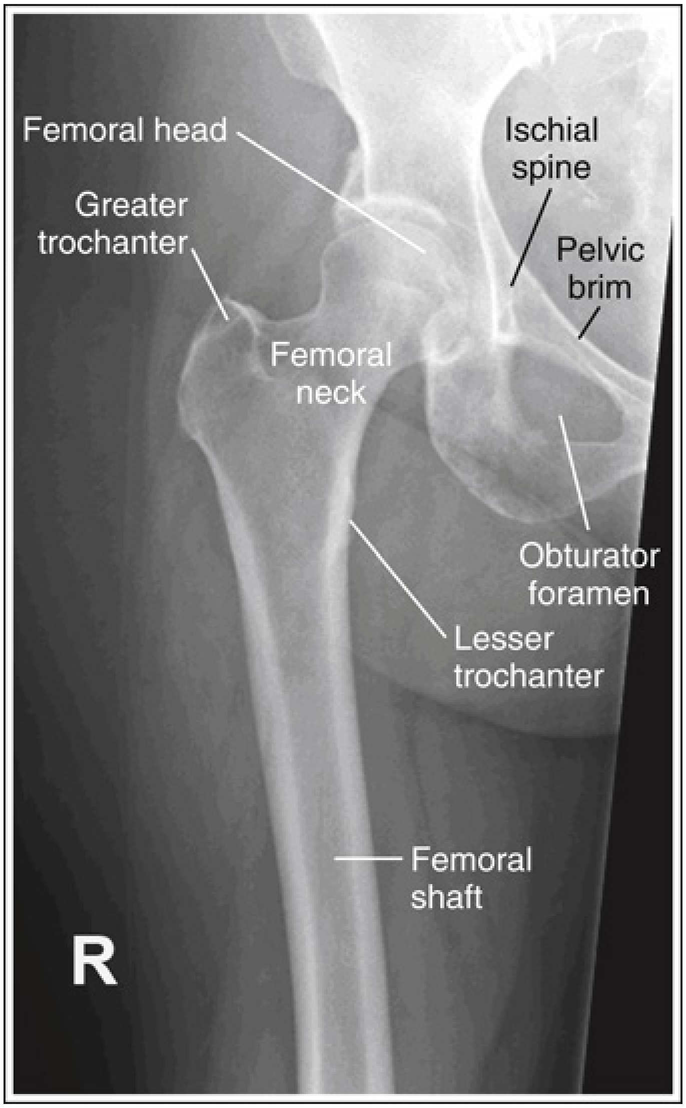


FIGURE 6.256 AP proximal femur projection with accurate positioning.

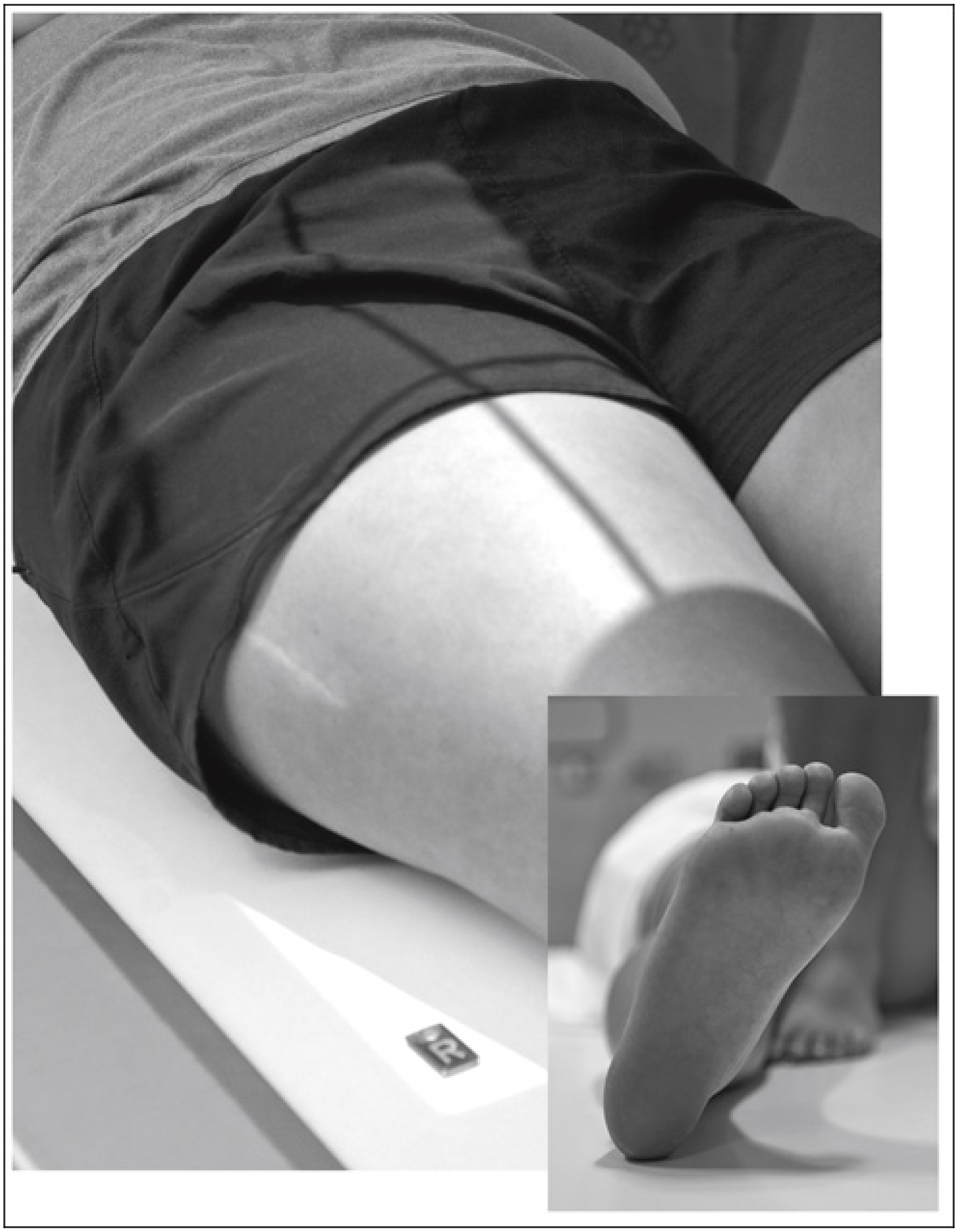


FIGURE 6.257 Proper patient positioning for AP proximal femur projection.

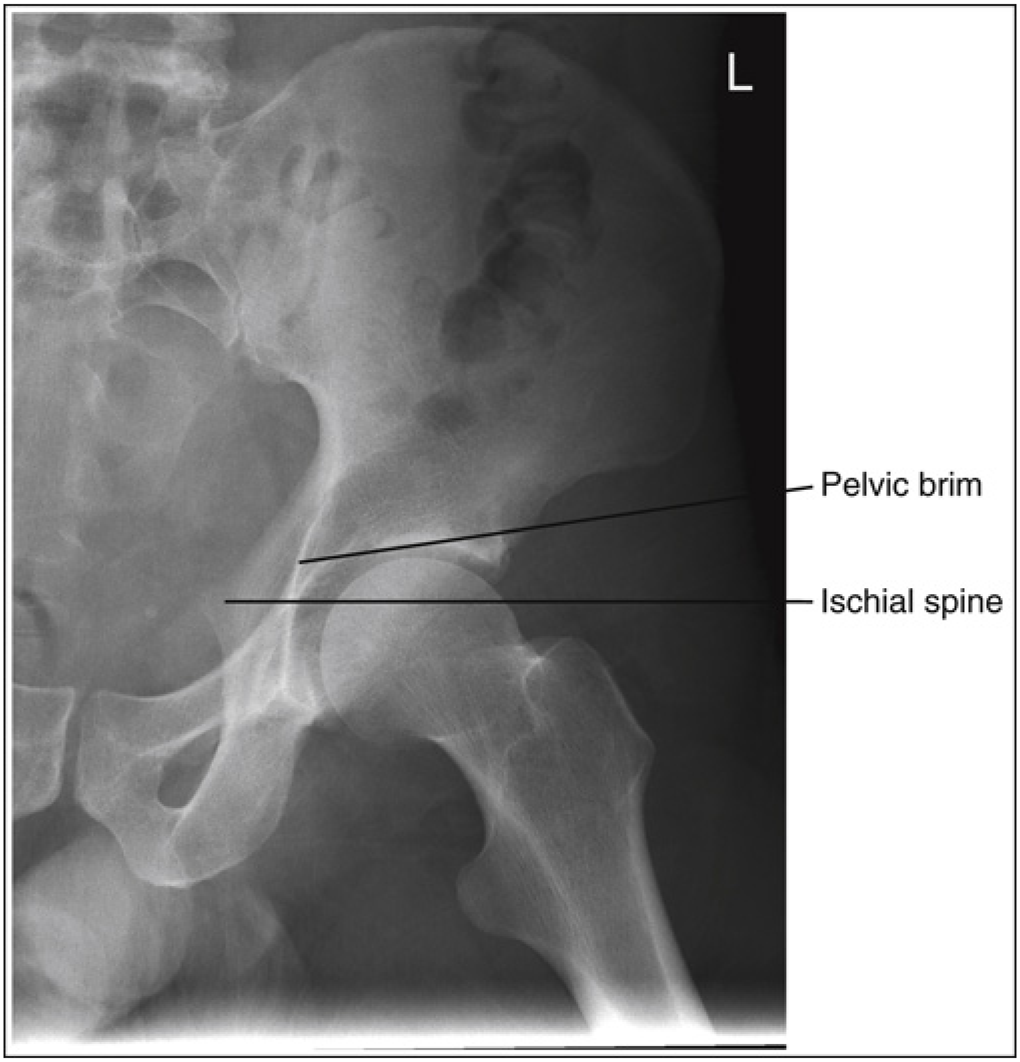


FIGURE 6.258 AP proximal femur projection taken with the pelvis rotated toward the affected femur and leg externally rotated.

TABLE 6.23

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

External Leg Rotation: Foot Vertical With the IR

If the leg is positioned with the foot placed vertically and the femoral epicondyles are at approximately a 15- to 20-degree external angle with the IR, the femoral neck is only partially foreshortened and the lesser trochanter is demonstrated in partial profile (**Fig. 6.261**).

FIGURE 6.259 AP proximal femur projection taken with the pelvis rotated away from the affected femur.

Positioning for Fracture: Leg Rotation

When a fracture of the femur is suspected, the leg should not be rotated, but left as is unless indicated by your facility. Because the leg is not internally

rotated when a fracture is in question, such an AP femoral projection demonstrates the femoral neck with some degree of foreshortening and the lesser trochanter without femoral shaft superimposition (**Fig. 6.262**).

Soft Tissue

The surrounding femoral soft tissue is included on an AP proximal femur projection to allow detection of subcutaneous air and hematomas.

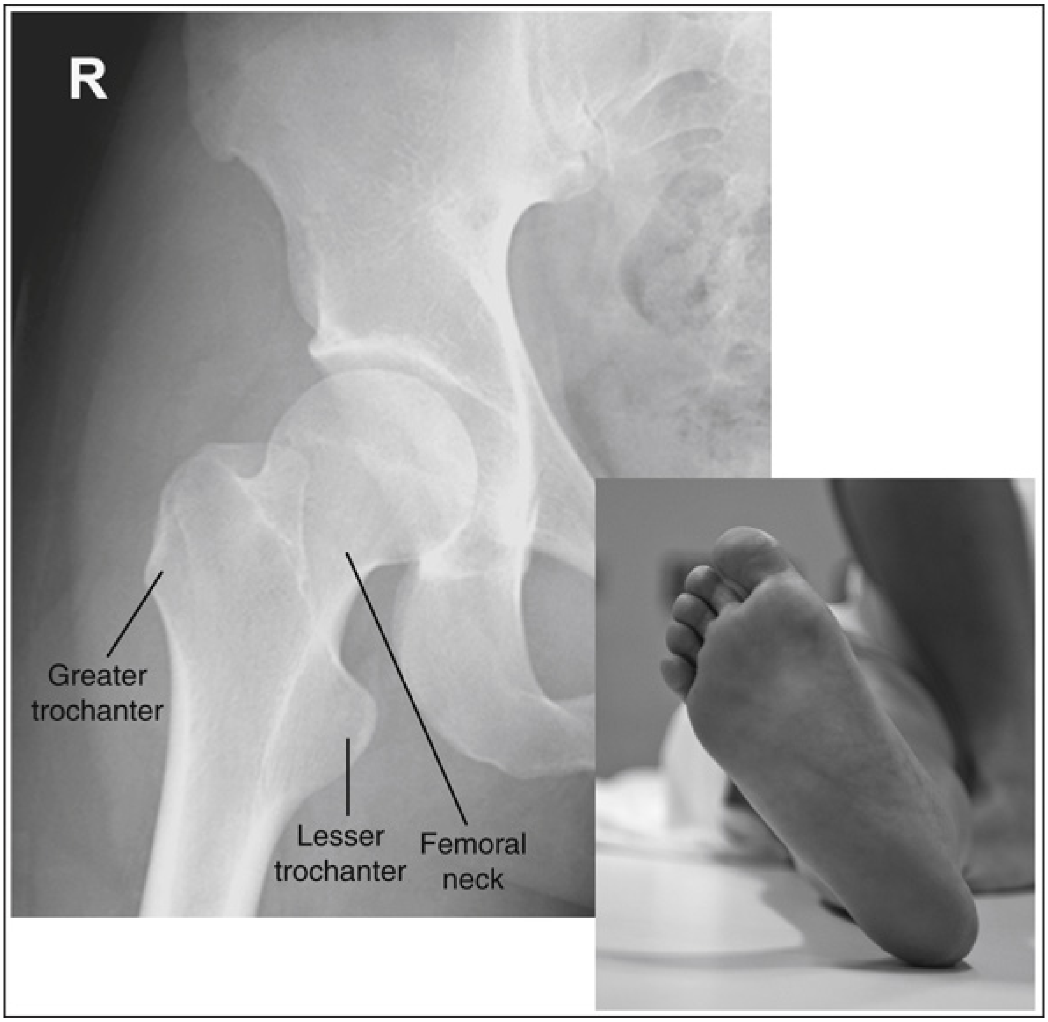


FIGURE 6.260 AP proximal femur projection taken with the leg externally rotated and the foot positioned at 45 degrees with the IR.

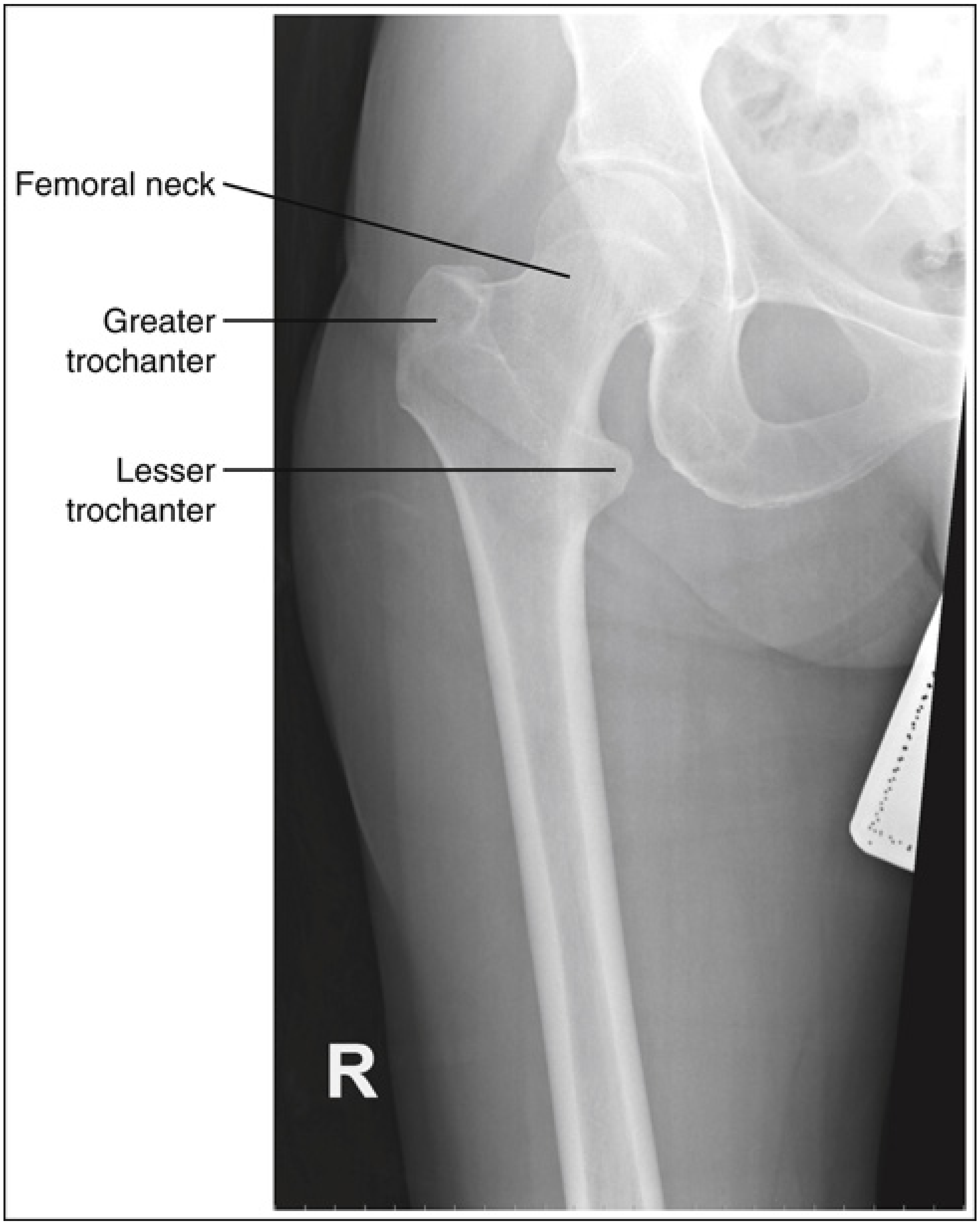


FIGURE 6.261 AP proximal femur projection taken with the foot positioned vertically.

FIGURE 6.262 AP proximal femur projection demonstrating a fracture.

AP Femur Analysis Practice

IMAGE 6.44

PROXIMAL FEMUR.

Analysis

The lesser trochanter is demonstrated in profile. The leg was externally rotated.

Correction

Internally rotate the leg until the foot is tilted 15 to 20 degrees from vertical, and the femoral epicondyles are positioned parallel with the imaging table.

Femur: Lateral Projection (Mediolateral)

Distal Femur

See **Table 6.24** and **Figs. 6.263** and **6.264**.

Internal Femur Rotation: Medial Femoral Condyle Posterior to Lateral Condyle

If the femoral epicondyles are not positioned perpendicular to the IR, the lateral projection demonstrates one femoral condyle anterior to the other condyle. Because the medial condyle is more distal than the lateral condyle and the CR is centered proximal to the knee joint for a lateral distal femur, x-ray divergence will cause the medial condyle to project distal to the lateral condyle about 0.5 inches (1.25 cm) when the mediolateral projection is obtained. Consequently, the distal condyle will be the medial condyle. If a lateral distal femur projection is obtained that demonstrates the medial condyle posterior to the lateral condyle, the leg was internally rotated (patella was situated too far away from the IR; **Fig. 6.265**).

External Femur Rotation: Medial Femoral Condyle Anterior to Lateral Condyle

If a lateral distal femur projection is obtained that demonstrates the medial condyle anterior to the lateral condyle, the leg was externally rotated

(patella was situated too close to the IR; **Fig. 6.266**).

Crosstable Lateromedial Projection: External Femur Rotation

When a fracture of the femur is suspected, the leg should not be internally rotated, but left as is, unless specified by your facility. In such cases, crosstable lateromedial knee projections are commonly performed, with the patient remaining in the supine position (**Fig. 6.267**). Because most fractured femurs are in external rotation, to obtain a lateromedial projection that demonstrates alignment of the anterior and posterior margins of the femoral condyles and the femur without rotation, it may be necessary to place an angled sponge under the affected hip to rotate the torso and femur away from the affected side as one unit, placing the femoral epicondyles as close to parallel with the IR as possible, and then if needed, angle the CR anteriorly until it is aligned parallel with the femoral epicondyles. If a grid is used, it is adjusted so that the gridlines are running with the CR angulation to prevent grid cutoff. Failure to angle anterior enough to align the CR and epicondyles parallel with each other will result in a projection that demonstrates the medial condyle anterior to the lateral condyle.

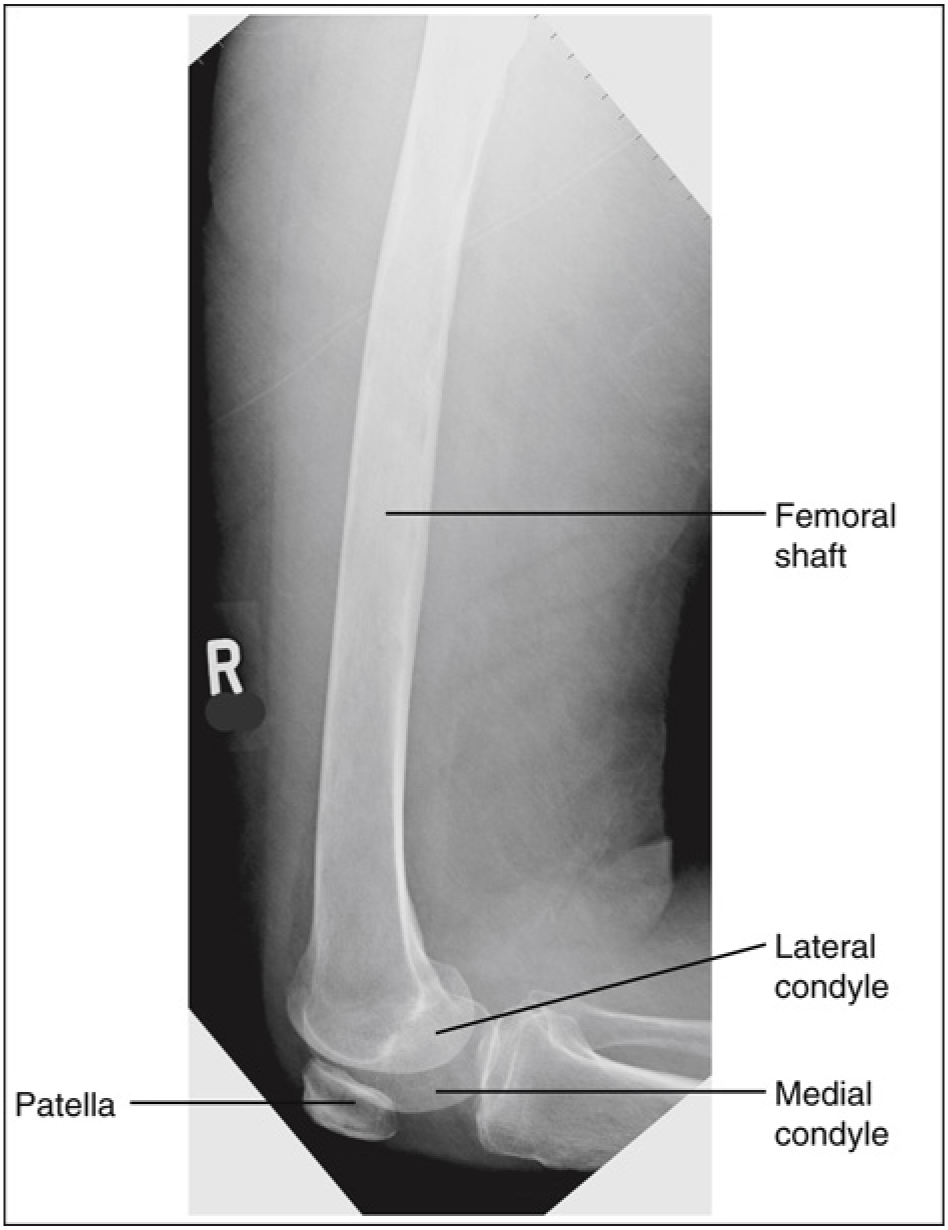


FIGURE 6.263 Lateral distal femur projection with accurate positioning.

FIGURE 6.264 Proper patient positioning for lateral distal femur projection.

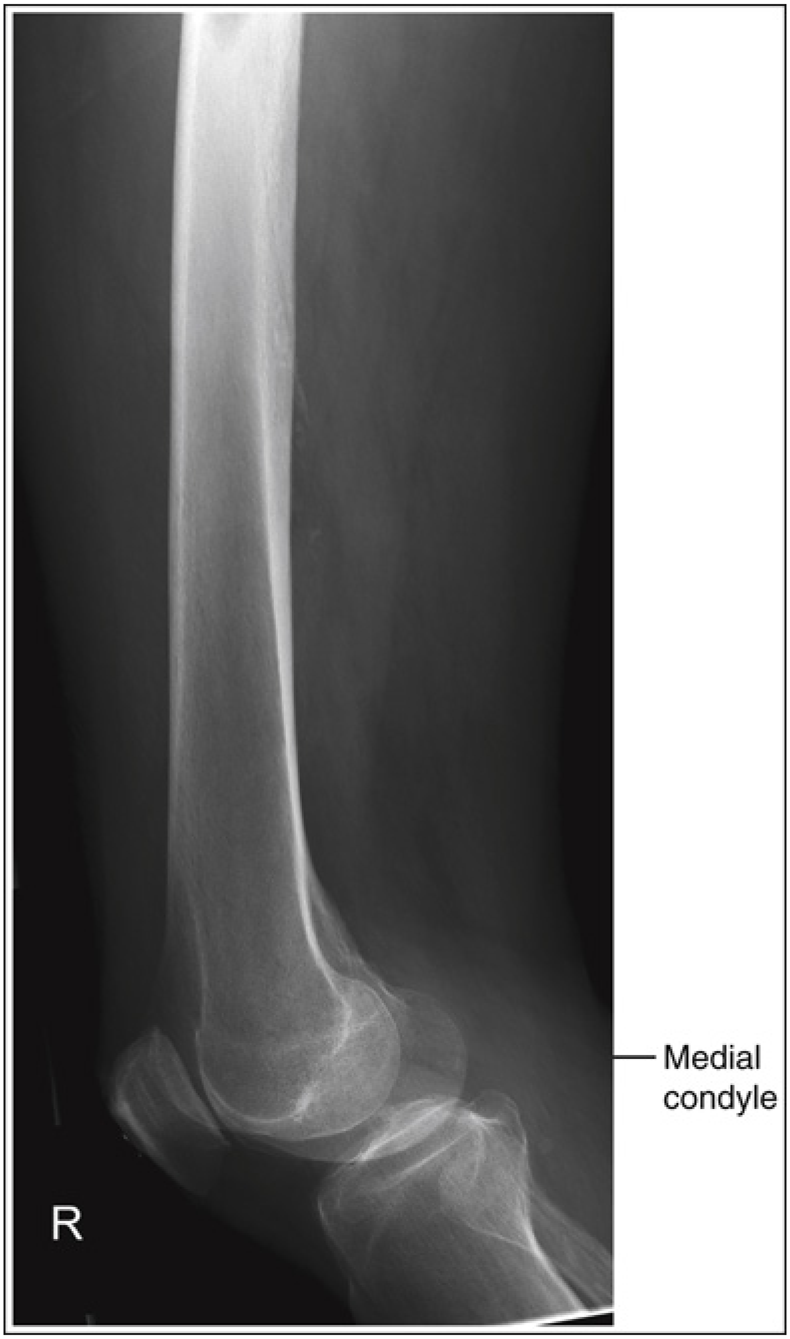


FIGURE 6.265 Lateral distal femur projection taken with the leg internally rotated.

FIGURE 6.266 Lateral distal femur projection taken with the leg externally rotated.

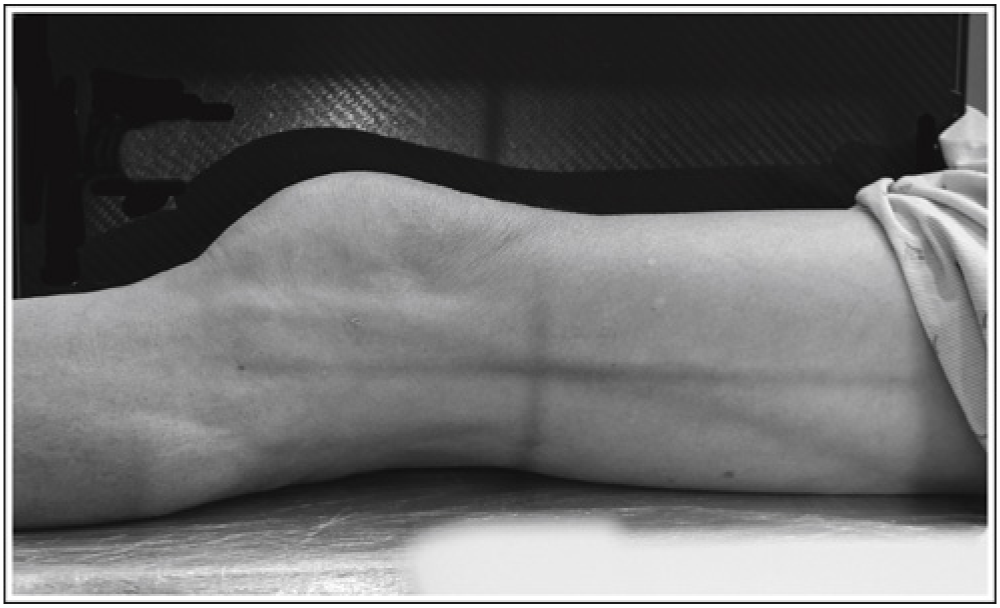


FIGURE 6.267 Proper patient positioning for crosstable lateromedial distal femur projection.

TABLE 6.24

CR, Central ray; *IR*, image receptor.

Crosstable Lateromedial Projection: Femoral Long Axis Alignment With IR

To demonstrate the femoral shaft without foreshortening on a crosstable lateromedial distal femur projection, the IR is aligned parallel with the femoral shaft and the x-ray tube is rotated proximally until the CR is aligned perpendicular to the femoral shaft and IR (**Fig. 6.268**). Because patients present different degrees of femoral inclination and leg abduction, the degree of proximal tube rotation that is needed will vary from patient to

patient. The resulting projection will demonstrate the femur without foreshortening and the lateral femoral condyle distal to the medial femoral condyle (**Fig. 6.269**).

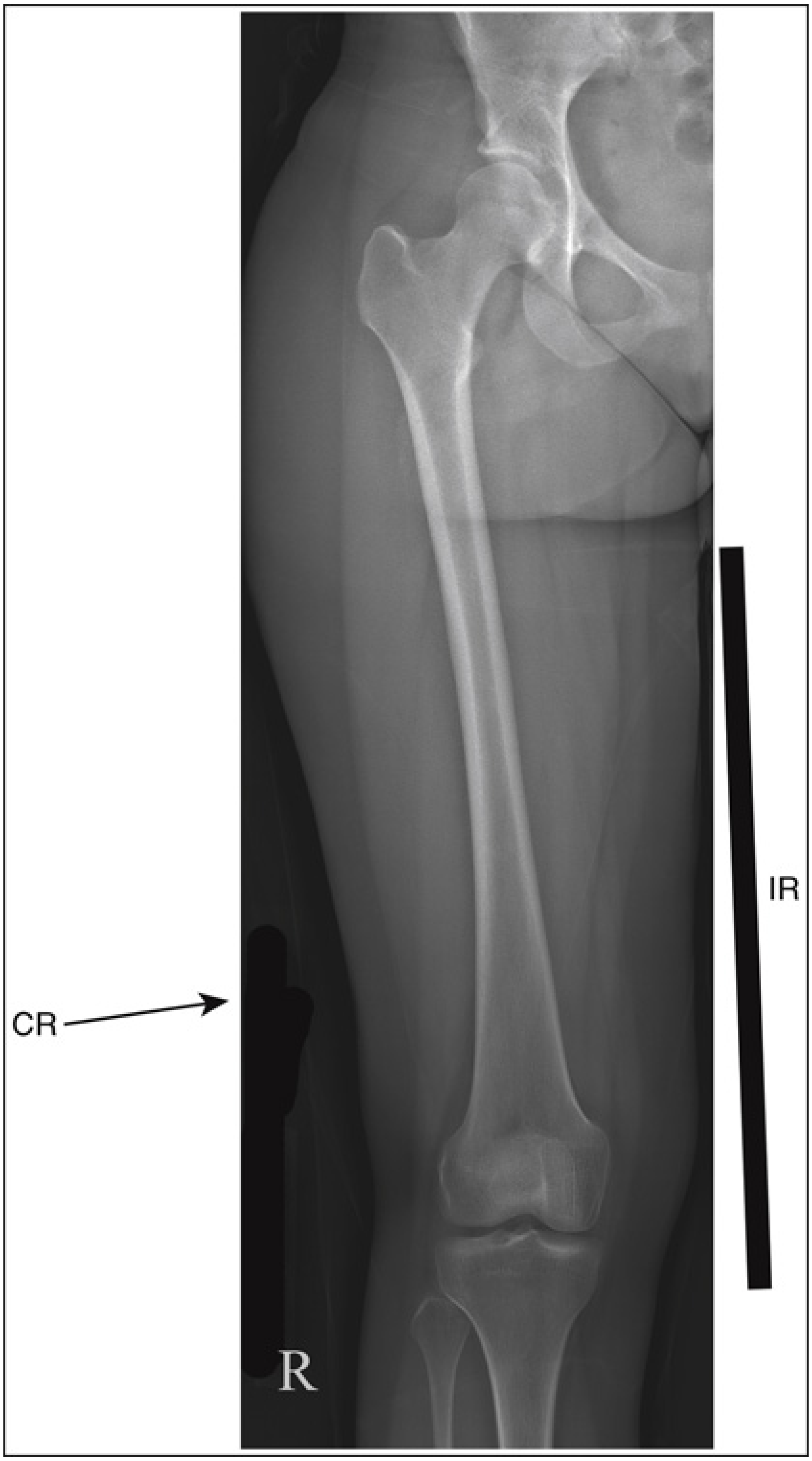

CR
IR
R

FIGURE 6.268 Accurate alignment of the CR, femur long axis, and IR for a crosstable lateral distal femur projection.

Femoral Shaft Overlap of Distal and Proximal Projections

Because the IR is not long enough to include the entire femur on one projection, to evaluate the entire femur, it is necessary to take two separate projections—one of the distal and the proximal femur. These projections need to demonstrate at least 2 inches (5 cm) of femoral shaft overlap. To prevent greater than a 2-inch (5 cm) femoral shaft overlap and provide appropriate radiation protection, one of the projections is collimated to a smaller size. When choosing whether the proximal or distal femur should be obtained with the longer field size, make certain that the overlapped area is not located at the section where a fracture or disease process is demonstrated (see **Fig. 6.269**).

Proximal Femur

See **Table 6.25** and **Figs. 6.270** and **6.271**.

Insufficient Femur and Pelvis Rotation

If the femur and pelvis are not rotated enough to place the femoral epicondyles perpendicular to the IR for a lateral proximal femur, the greater trochanter is not positioned beneath the neck and head but is partially demonstrated laterally and the lateral trochanter is partially demonstrated medially on the resulting projection (**Fig. 6.272**).

Excessive Femur and Pelvis Rotation

If the femur and pelvis are rotated more than needed to place the femoral epicondyles perpendicular to the IR for a lateral proximal femur, the greater trochanter is partially in profile medially and the lesser trochanter will be obscured on the resulting projection (**Fig. 6.273**).

Distal Femur Elevation: Femoral Shaft Foreshortening

To understand the relationship between the femoral shaft and neck, study a femoral skeletal bone placed in a lateral projection. Note that when the femur rests against a flat surface in a lateral projection, the femoral shaft is demonstrated without foreshortening, and the femoral neck is on end and completely foreshortened and cannot be evaluated on a projection taken in this manner. If instead of being positioned flat against the imaging table, the distal femur is elevated for the projection, the femoral shaft is shown with increased foreshortening, the femoral neck is shown with decreased foreshortening, and the greater trochanter will be at a transverse level distal to the femoral head on the resulting projection (**Fig. 6.274**). The higher the distal femur is elevated, the greater will be the changes.

Collimation

If the femur does not align with the midline of the grid and IR, resulting in a need to decrease the amount of transverse collimation to include all the required anatomical structures, increased transverse collimation can be obtained by rotating the collimator head until one of its axes is aligned with the long axis of the femur (**Fig. 6.275**).

Positioning for Fracture

For a patient with a suspected or known fracture, rotating, flexing, or abducting the affected leg or rolling the patient onto the affected side may cause further soft tissue and bony injury. Therefore an axiolateral projection

of the proximal femur should be used (Figs. 6.276–6.278). Refer to the axiolateral hip projection in Table 7.7 in Chapter 7 for image analysis guidelines and related positioning procedures for this projection.

FIGURE 6.269 Lateral distal femur projections demonstrating how it is best to keep the collimation open to include the entire fracture site on one projection.

FIGURE 6.270 Lateral proximal femur projection with accurate positioning.

FIGURE 6.271 Proper patient positioning for lateral proximal femur projection.

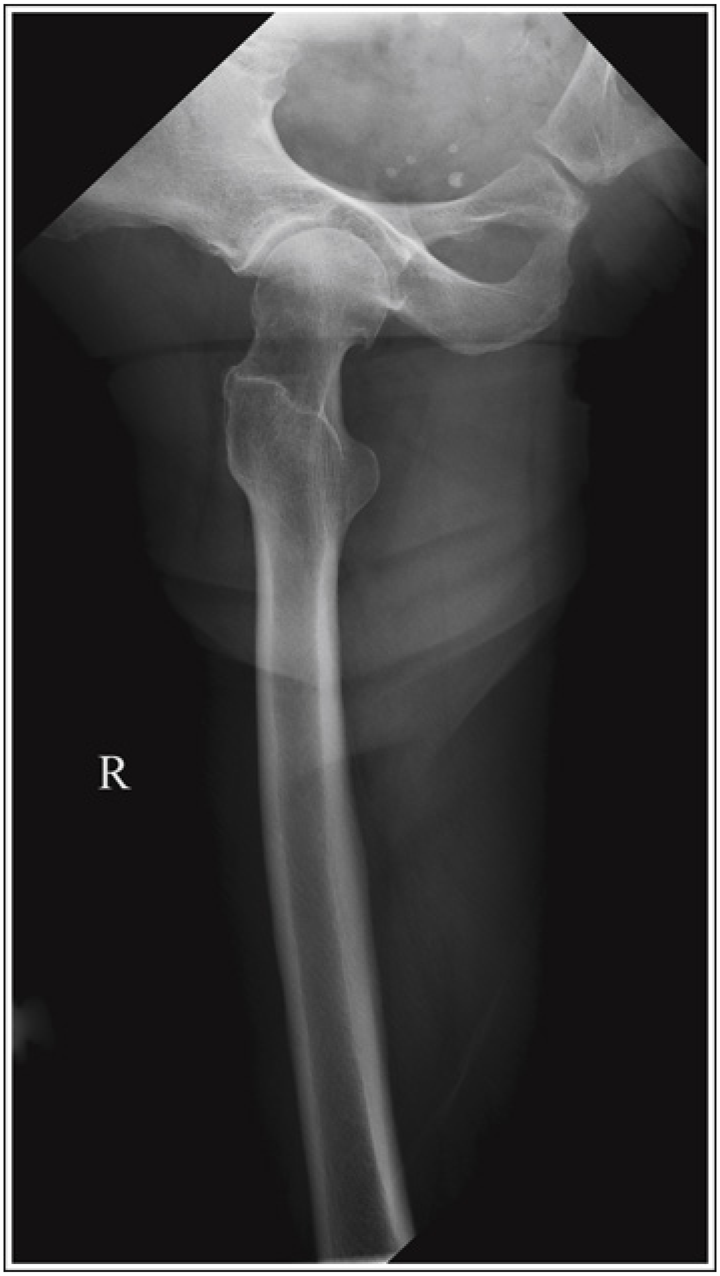


FIGURE 6.272 Lateral proximal femur projection taken with the leg and pelvis insufficiently rotated to place the femoral epicondyles perpendicular to the IR.

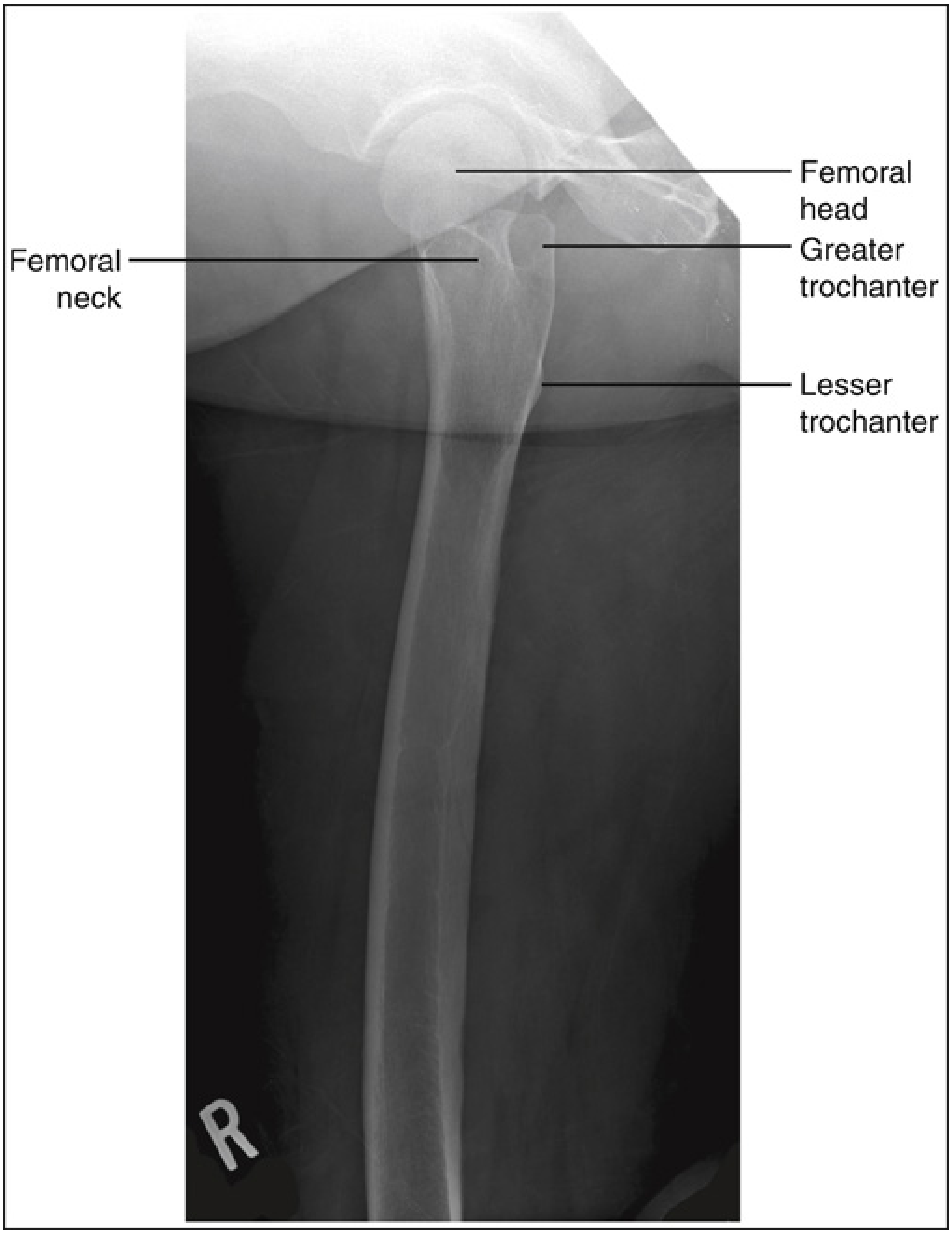


FIGURE 6.273 Lateral proximal femur projection taken with the leg and pelvis excessively rotated.

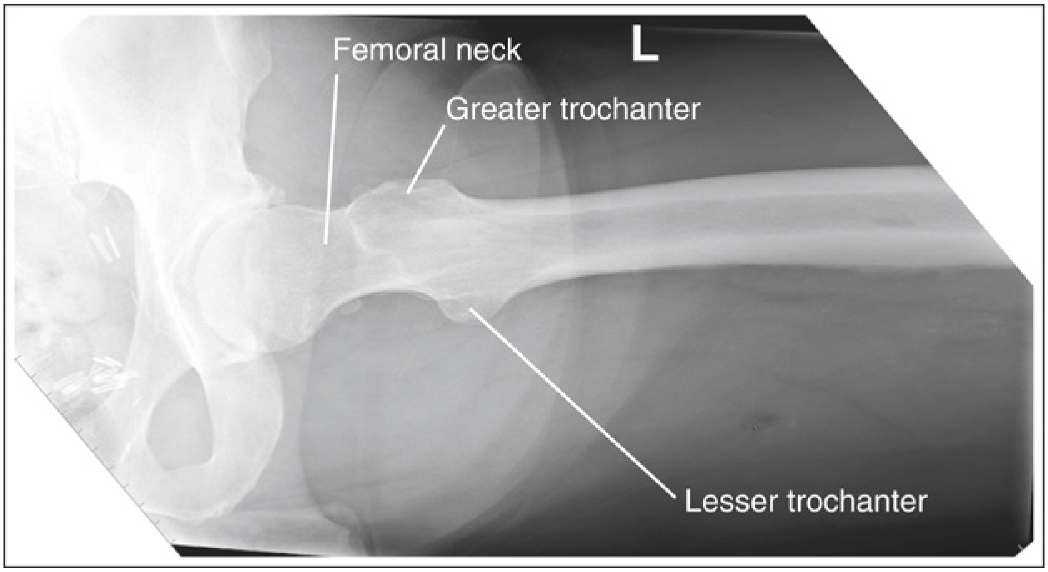


FIGURE 6.274 Lateral proximal femur projection taken with the distal femur elevated.

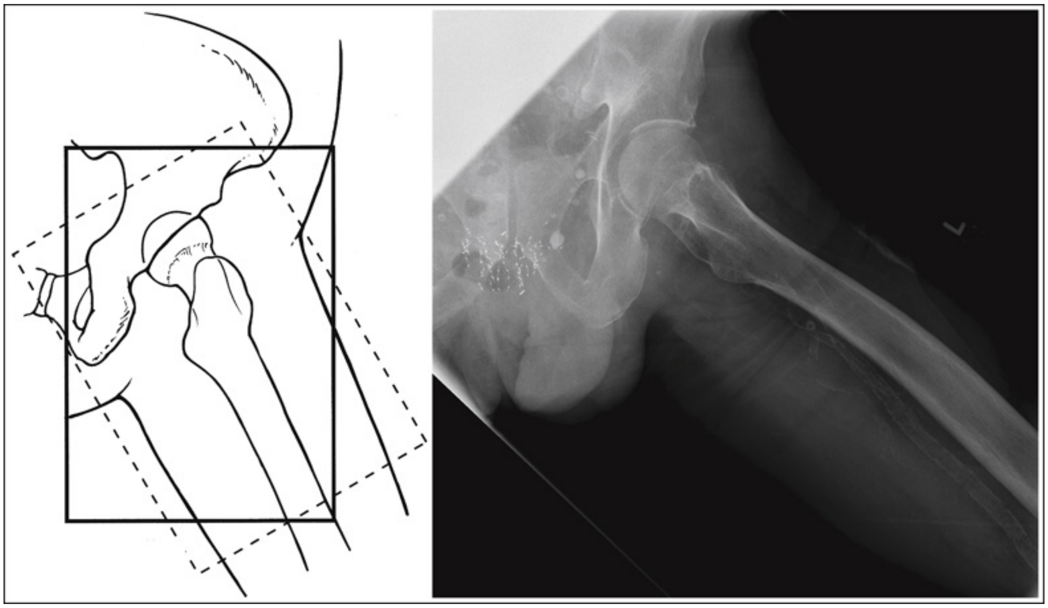


FIGURE 6.275 CR centering for proximal femur projection. *Dotted line rectangle* indicates area covered if collimator head is turned.

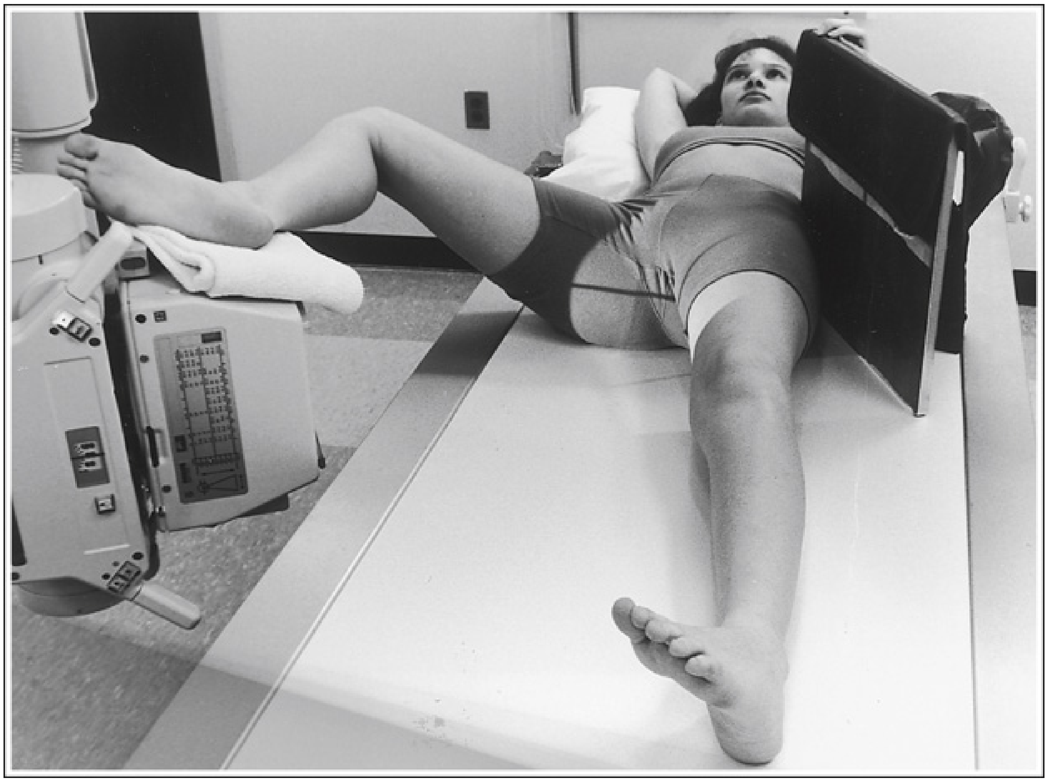


FIGURE 6.276 Positioning for proximal femur fracture.

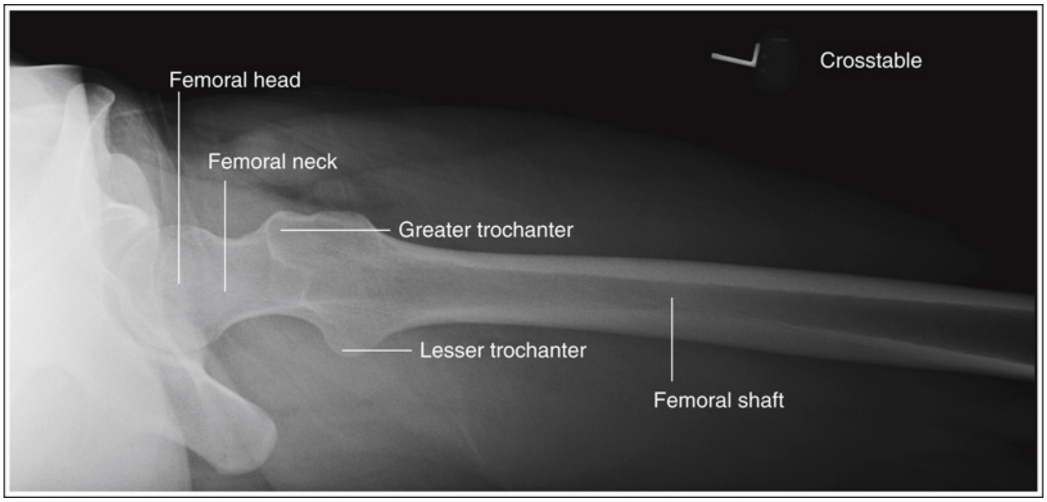


FIGURE 6.277

CROSSTABLE LATERAL PROXIMAL FEMUR PROJECTION WITH ACCURATE POSITIONING.

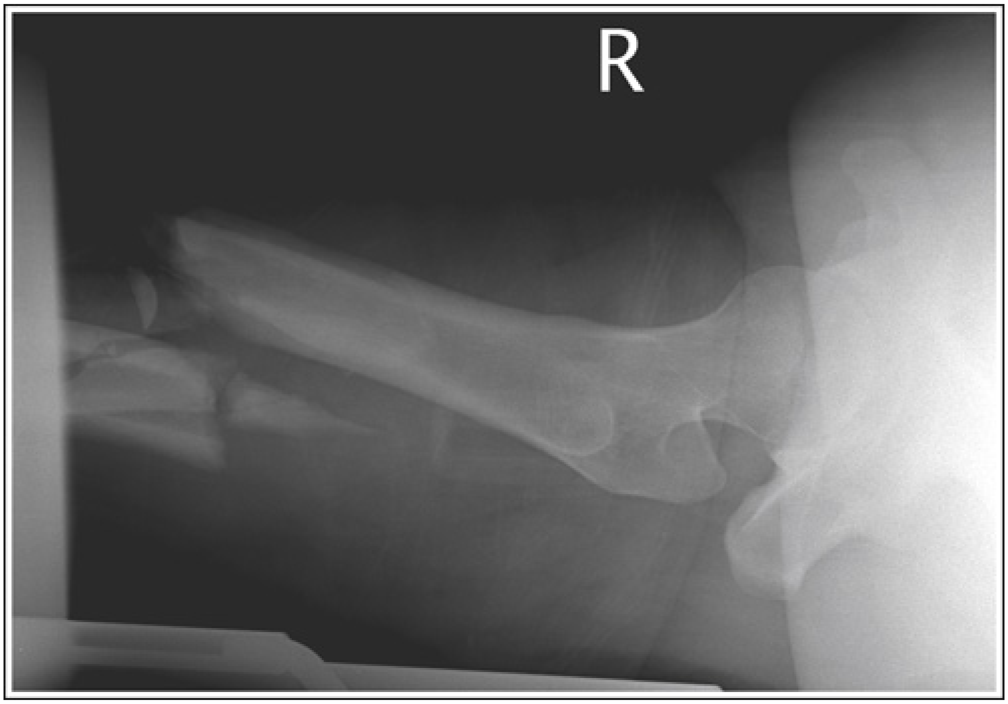


FIGURE 6.278 Proximal femur projection with fracture.

TABLE 6.25

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

Lateral Femur Image Analysis Practice

IMAGE 6.45

DISTAL FEMUR.

Analysis

The medial condyle is positioned anterior to the lateral condyle. The patella was situated too close to the IR (leg externally rotated).

Correction

Internally rotate the leg until the femoral epicondyles are positioned perpendicular to the IR.

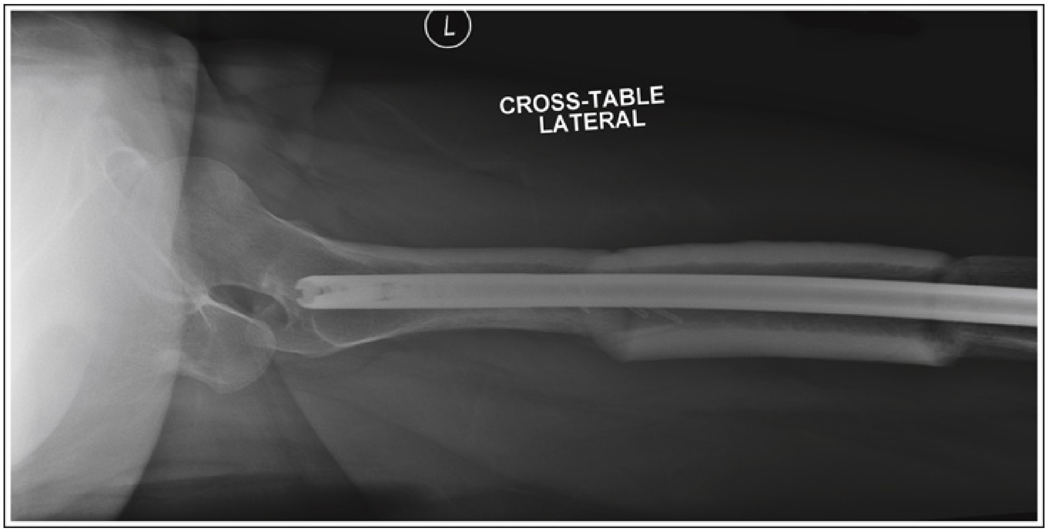


IMAGE 6.46

PROXIMAL FEMUR.

Analysis

The greater trochanter is demonstrated posteriorly and the lesser trochanter is not seen. The leg was not internally rotated.

Correction

Internally rotate the leg until the femoral epicondyles are positioned perpendicular to the IR.

Chapter 7: Image Analysis of the Pelvis and Hip

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Identify the required anatomy on projections of the hip, pelvis, and sacroiliac (SI) joints.
- Describe how to position the patient, image receptor (IR), and central ray (CR) properly for hip, pelvic, and SI joint projections.
- List the requirements for accurate positioning for hip, pelvic, and SI joint projections.
- State how to reposition the patient properly when hip, pelvic, and SI joint projections with poor positioning are produced.
- Discuss how to determine the amount of patient or CR adjustment required to improve hip, pelvic, and SI joint projections with poor positioning.

- List the soft tissue fat planes demonstrated on anteroposterior (AP) hip and pelvic projections, and describe their locations.
- Explain how leg rotation affects which anatomic structures of the proximal femur are demonstrated.
- Explain the structures that are best demonstrated on the AP oblique (Judet), AP axial outlet, and superoinferior axial inlet pelvis projections.
- Discuss why the leg of a patient with a proximal femoral fracture should never be rotated to obtain AP and lateral projections, and state how these projections should be taken.
- Define the differences demonstrated between the pelvic bones of female and male patients.
- Describe how the anatomic structures of the proximal femur are demonstrated differently for frog-leg hip and pelvic projections when the distal femur is abducted at different angles with the IR.
- Describe how to localize the femoral neck for an axiolateral hip projection.
- State which SI joint is of interest when the patient is rotated for oblique SI joint projections.

KEY TERMS

gluteal fat plane

iliopsoas fat plane

obturator internus fat plane

pericapsular fat plane

Image Analysis Guidelines

Technical Data

See **Table 7.1** and **Box 7.1**.

Pelvis: AP Projection

See **Table 7.2** and Figs. **7.1**–**7.4**.

Fat Planes

When evaluating pelvic projections, the reviewer not only analyzes the bony structures but also studies the placement of the soft tissue fat planes. Four fat planes are of interest on anteroposterior (AP) pelvis and hip projections, and their visualization aids in the detection of intra-articular and periarticular disease: the obturator internus fat plane, which lies within the pelvic inlet next to the medial brim; the iliopsoas fat plane, which lies medial to the lesser trochanter; the pericapsular fat plane, which is found superior to the femoral neck; and the gluteal fat plane, which lies inferior and lateral to the pericapsular fat plane (see **Fig. 7.3**).

Differences Between Male and Female Pelves

When evaluating the AP pelvis projection be aware of the bony architectural differences that exist between the male and female pelves (**Table 7.3**; see **Figs. 7.1** and **7.4**). These differences are the result of the need for the female pelvis to accommodate fetal growth during pregnancy and fetal passage during delivery.

Pelvis Rotation: LPO Position

If the pelvis is rotated into a left posterior oblique (LPO) position, the left iliac wing demonstrates less foreshortening than the right, the left ischial

spine is de monstrated without pelvic brim superimposition, the left obturator foramen demonstrates more foreshortening than the right, and the sacrum and coccyx are not aligned with the pubis symphysis but are rotated toward the right hip (**Fig. 7.5**).

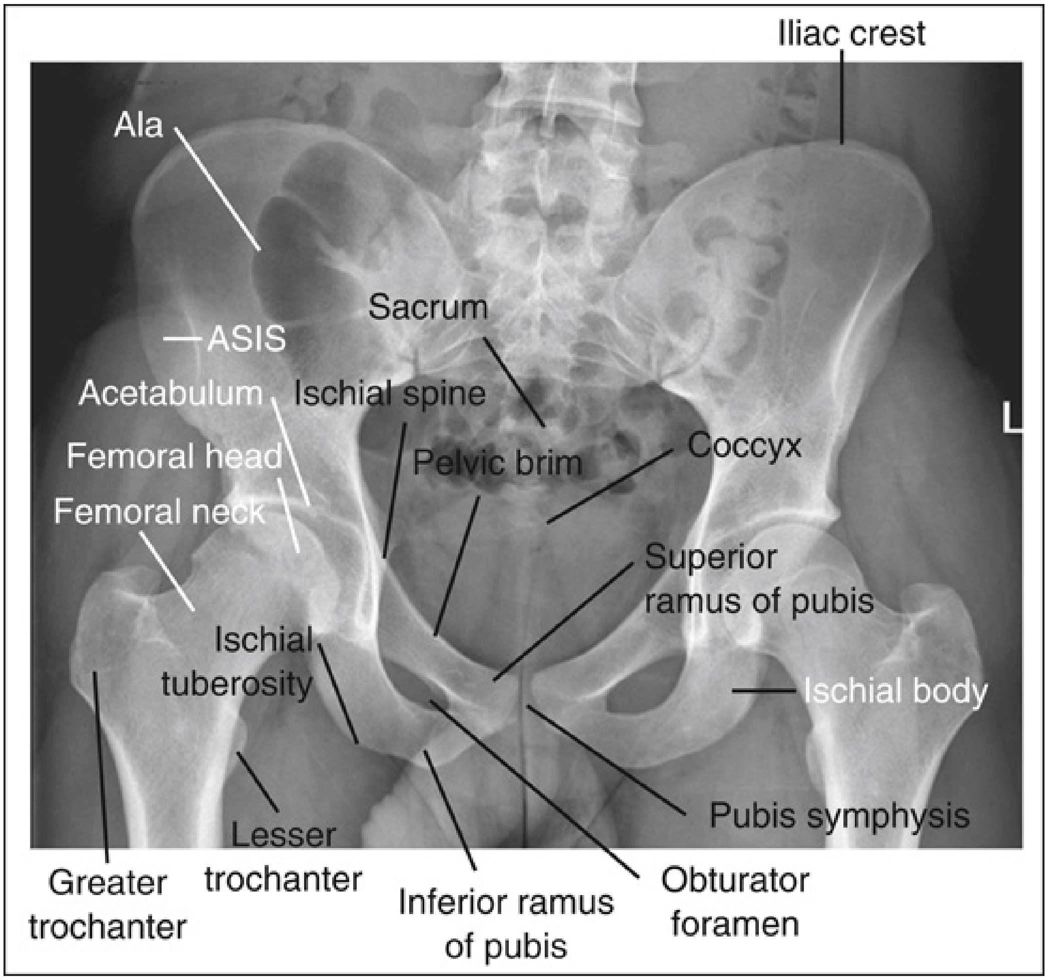


FIGURE 7.1 AP male pelvis projection with accurate positioning.

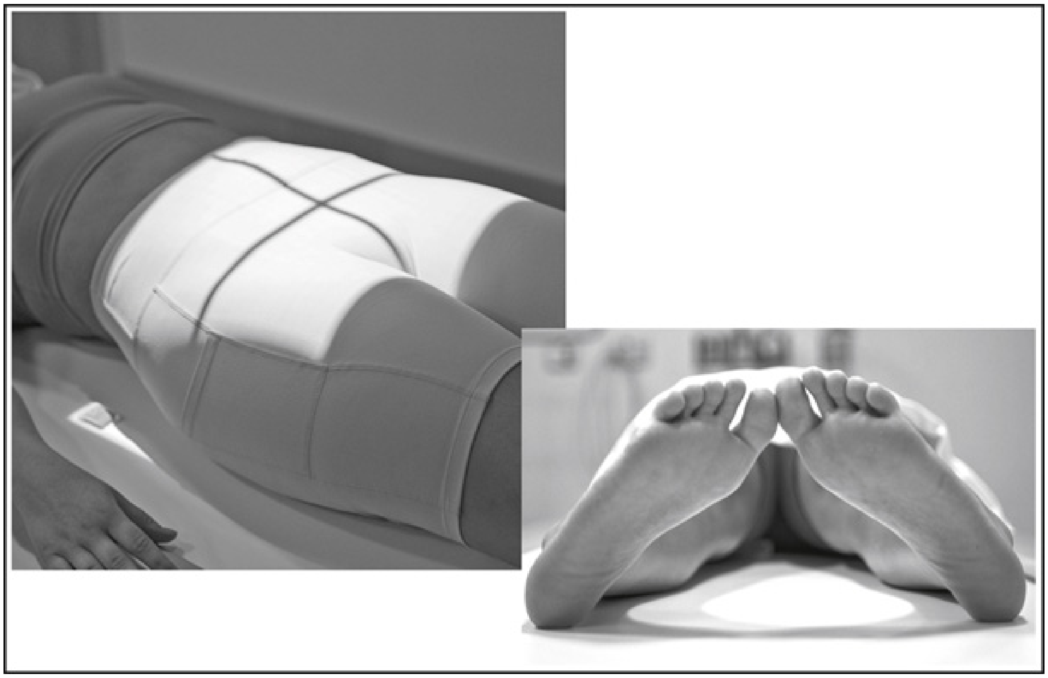


FIGURE 7.2 Proper patient positioning for AP pelvis projection.

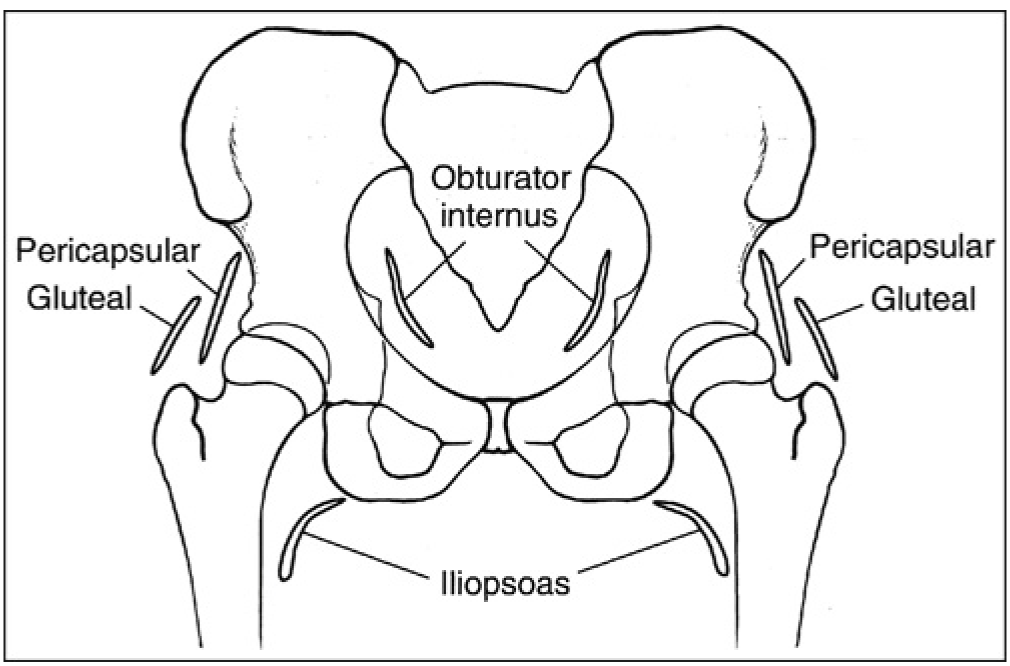


FIGURE 7.3 Location of fat planes.

FIGURE 7.4 AP female pelvis projection with accurate positioning.

FIGURE 7.5 AP pelvis projection taken with the pelvis rotated toward the left side (LPO position).

TABLE 7.1

Use grid if part thickness measures 4 inches (10 cm) or more and adjust mAs per grid ratio requirement.

AEC, Automatic exposure control; *AP*, anteroposterior; *SID*, source–IR distance.

TABLE 7.2

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

TABLE 7.3

Male and Female Pelvic Differences

Parameter	Male (Fig. 7.1)	Female (Fig. 7.4)
Overall shape	Bulkier, deeper, narrower	Smaller, shallower, and wider
Ala (iliac wing)	Narrower, nonflared	Wider, flared
Pubic arch angle	Acute angle	Obtuse angle
Inlet shape	Smaller, heart shaped	Larger, rounded shape
Obturator foramen	Larger	Smaller

Box 7.1 Hip and Pelvis Guidelines

- The facility's identification requirements are visible.

- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomical structures are sharply defined.
- Contrast resolution is adequate to demonstrate the surrounding soft tissue, bony trabecular patterns, and cortical outlines.
- No quantum mottle or saturation is present.
- Scatter radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

VOI, Values of interest.

Pelvis Rotation: RPO Position

If the pelvis is rotated into a right posterior oblique (RPO) position, the right iliac wing demonstrates less foreshortening than the left, the right ischial spine is demonstrated without pelvic brim superimposition, the right obturator foramen demonstrates more foreshortening than the left, and the sacrum and coccyx are rotated toward the left hip (**Fig. 7.6**).

External Leg Rotation

When patients are supine and relaxed, their legs and feet are typically in external rotation. On external rotation the femoral necks decline posteriorly and demonstrate foreshortening on an AP pelvis projection. The greater the degree of external rotation, the greater are the posterior decline and foreshortening of the femoral necks. If the legs are externally rotated enough to position the feet at a 45-degree angle, with the femoral epicondyles at a 60- to 65-degree angle with the image receptor (IR), the

femoral necks are demonstrated on end and the lesser trochanters are demonstrated in profile (**Figs. 7.7** and **7.8**).

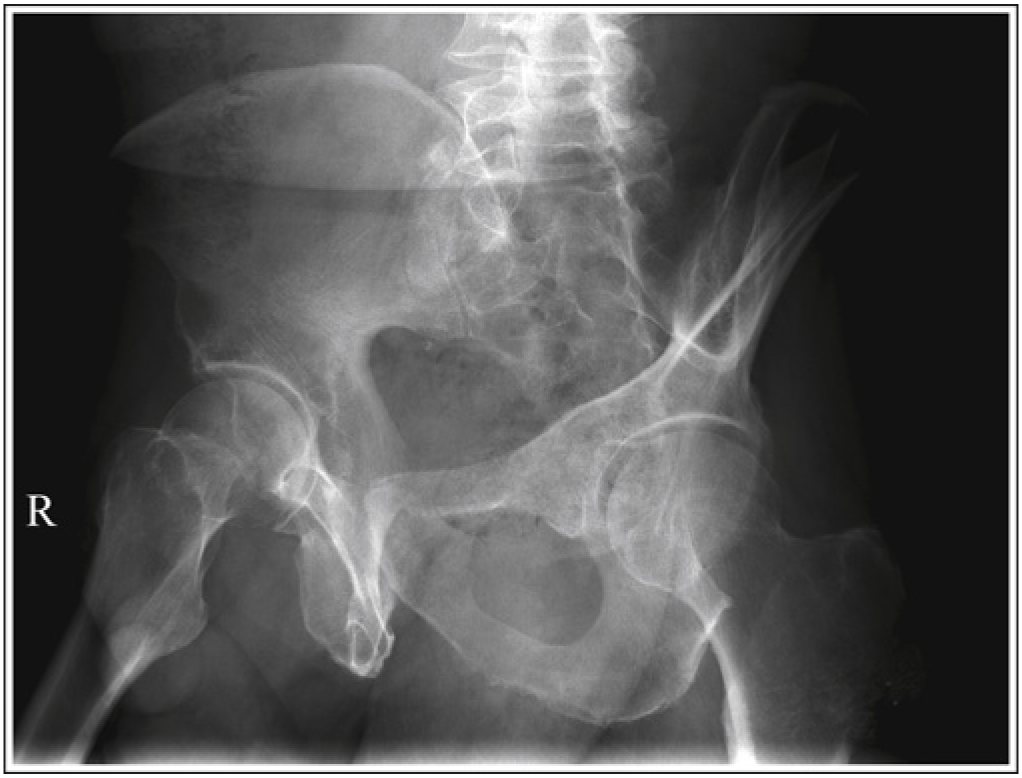


FIGURE 7.6 AP pelvis projection taken with the pelvis rotated into a RPO position.

FIGURE 7.7 Poor foot positioning.

Insufficient Internal Leg Rotation

If the legs are positioned with the feet placed vertically, with the femoral epicondyles at approximately a 15- to 20-degree angle with the IR, the lesser trochanter is demonstrated in partial profile and the femoral neck is only partially foreshortened (**Fig. 7.9**).

Proximal Femur or Femoral Neck Fracture

Often when a fracture of the proximal femur or femoral neck is suspected, a pelvic projection is ordered instead of an AP projection of the affected hip. This is because pelvic fractures are frequently associated with proximal femur fractures. If a patient has a suspected proximal femur or femoral neck fracture, the leg(s) should not be internally rotated but should be left as is unless indicated by your facility. If the leg is not internally rotated when a proximal femur or femoral neck fracture is in question, such a pelvic projection demonstrates the affected femoral neck with some degree of

foreshortening and the lesser trochanter without femoral shaft superimposition (**Fig. 7.10**).

FIGURE 7.8 AP pelvis projection taken with the legs externally rotated enough to position the feet at a 45-degree angle with the IR.

FIGURE 7.9 AP pelvis projection taken with the feet placed vertical and the femoral epicondyles at a 60- to 65-degree angle with the IR.

Hip Dislocation

When an AP pelvis projection is requested and a hip dislocation is suspected, the affected leg should not be internally rotated but left as it is. The resulting projection will demonstrate the femoral head superior to the acetabulum (**Fig. 7.11**).

Total Hip Replacement

A radiopaque templating marker is placed in the exposure field on preoperative total hip replacement (THR) AP pelvis and hip projections to determine the magnification factor, which is then used by surgeons to determine the size of the implant that is needed and to anticipate problems

that might arise due to abnormalities of mechanical alignment and bone structures (**Fig. 7.12**).

FIGURE 7.10 AP pelvis projection of a patient with a right femoral neck fracture.

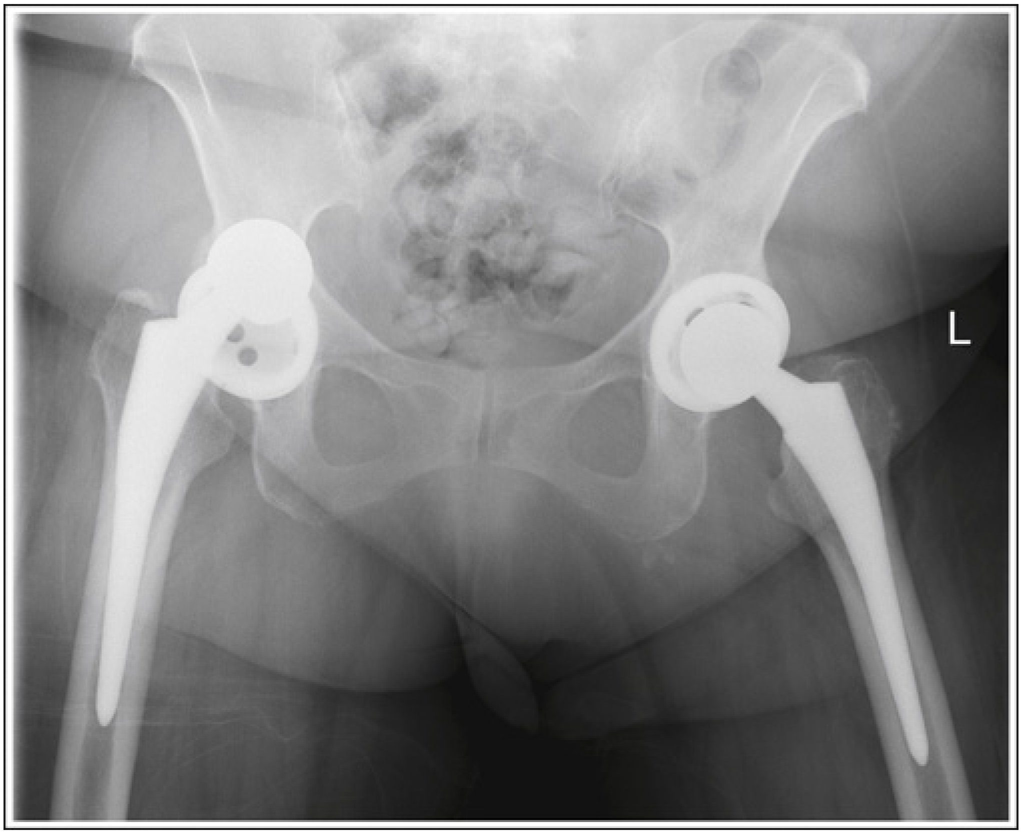


FIGURE 7.11 AP pelvis projection demonstrating a dislocation of a right total hip replacement.

Hip and Proximal Femur Orthopedic Apparatuses

When an AP pelvis projection is requested and the patient has had an orthopedic apparatus placed in the hip joint or proximal femur, the entire apparatus is to be included on the resulting projection. This may require more distal placement of the IR and more distal central ray (CR) centering (see **Fig. 7.12**). The superior ilia may also be clipped on the resulting projection. This is an acceptable guideline for this condition.

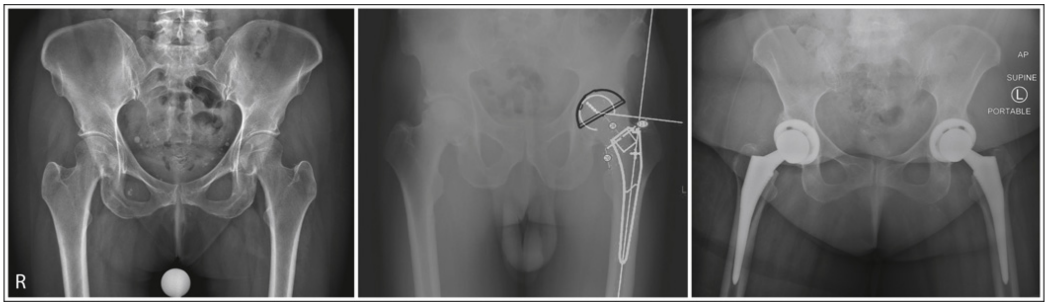


FIGURE 7.12 Total hip replacement preoperative and postoperative AP pelvis projections with templating.

AP Pelvis Analysis Practice

IMAGE 7.1

Analysis

The left obturator foramen is more foreshortened than the right, the left iliac wing is less foreshortened than the right, and the sacrum and coccyx are rotated toward the right hip. The lesser trochanters are demonstrated medially and the femoral necks are foreshortened. The pelvis was rotated onto the left side (LPO) and the legs were externally rotated.

Correction

Rotate the pelvis toward the right hip until the anterior superior iliac spines (ASISs) are positioned at equal distances from the IR, and internally rotate the legs until the foot is angled 15 to 20 degrees from vertical and the femoral epicondyles are positioned parallel with the table.

Pelvis: AP Frog-Leg Projection (Modified Cleaves Method)

See **Table 7.4** and **Figs. 7.13** and **7.14**.

Pelvis Rotation: LPO Position

If the pelvis is rotated into an LPO position, the left ilium demonstrates less foreshortening than the right ilium, the left ischial spine is demonstrated without pelvic brim superimposition, the left obturator foramen demonstrates more foreshortening than the right, and the sacrum and coccyx are not aligned with the pubis symphysis but are rotated toward the right hip (**Fig. 7.15**).

Pelvis Rotation: RPO Position

If the pelvis is rotated into an RPO position, the opposite is true. The right ilium demonstrates less foreshortening than the left, the right ischial spine is demonstrated without pelvic brim superimposition, the right obturator

foramen demonstrates more foreshortening than the left, and the sacrum and coccyx are rotated toward the left hip.

Lesser and Greater Trochanter Positioning

For an AP frog-leg pelvis and hip projections, the medial and lateral placement of the greater and lesser trochanters is determined when the patient flexes the knee and hip. Use a femoral skeletal bone for a better understanding of how the relationship of the greater and lesser trochanters to the proximal femur changes as the distal femur is elevated with knee and hip flexion. Begin by placing the femoral bone on a flat surface in an AP projection. While slowly elevating the distal femur, observe how the greater trochanter rotates around the proximal femur. First, the greater trochanter moves beneath the proximal femur; then, as elevation of the distal femur continues, it moves from beneath the proximal femur and is demonstrated on the medial side of the femur. To position the greater trochanter accurately beneath the proximal femur and position the lesser trochanter in profile, flex the knee and hip until the femur is angled at 60 to 70 degrees with the IR (20 to 30 degrees from vertical) (**Fig. 7.16**).

Insufficient Knee and Hip Flexion

If the knees and hips are not flexed enough to place the femur at a 60- to 70-degree angle with the IR for an AP frog-leg pelvis, the greater trochanters are demonstrated in partial profile laterally on the resulting projection (**Fig. 7.17**).

Excessive Knee and Hip Flexion

If the knees and hips are flexed too much for an AP frog-leg pelvis, placing the femurs at an angle greater than 60 to 70 degrees with the IR, the greater

trochanters are demonstrated medially on the resulting projection (**Fig. 7.18**).

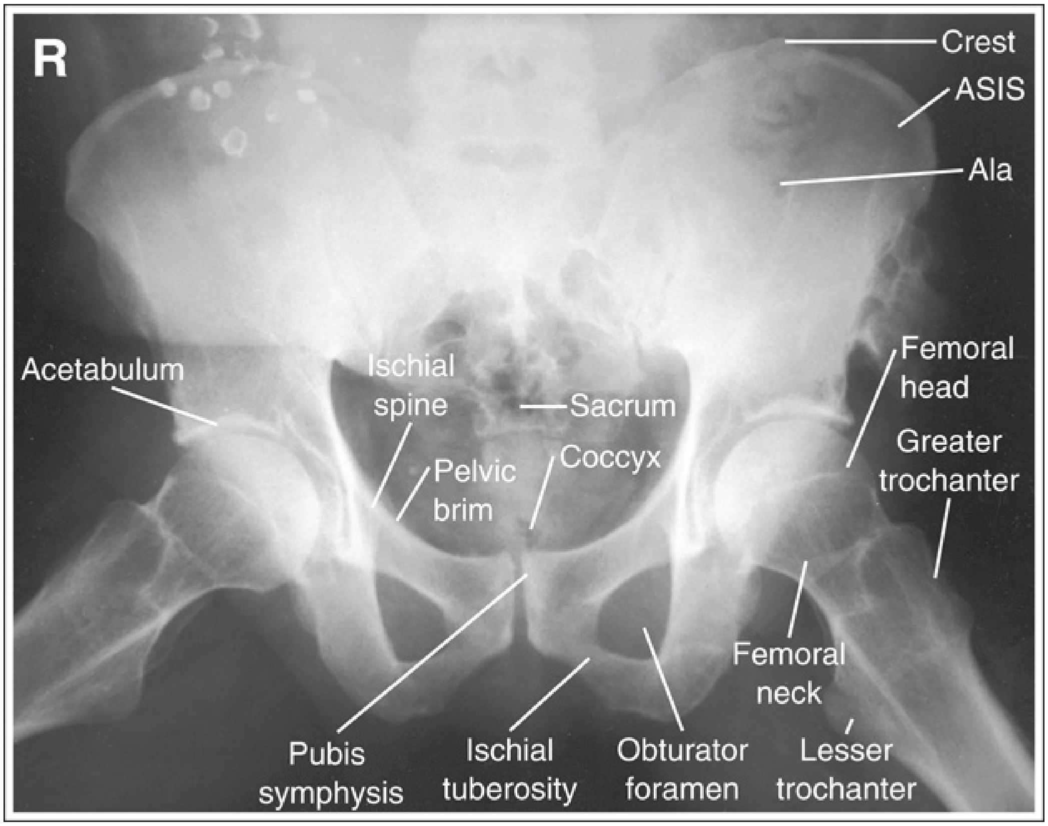


FIGURE 7.13 AP frog-leg pelvis projection with accurate positioning.

TABLE 7.4

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

Femoral Abduction

The degree of femoral abduction determines the amount of femoral neck foreshortening and the transverse level at which the greater trochanters are demonstrated between the femoral heads and lesser trochanters. Place the femoral bone on a flat surface in an AP projection, with the distal femur elevated until the greater trochanter is positioned beneath the proximal femur and the lesser trochanter is in profile (20 to 30 degrees from vertical or 60 to 70 degrees from flat surface). From this position, abduct the femoral bone (move the lateral surface of the femoral bone toward the flat surface). As the bone moves toward the flat surface, observe how the femoral neck is positioned more on end and the greater trochanter moves proximally (toward the femoral head). An AP frog-leg projection of the pelvis may not demonstrate the proximal femurs with exactly the same degree of femoral abduction.

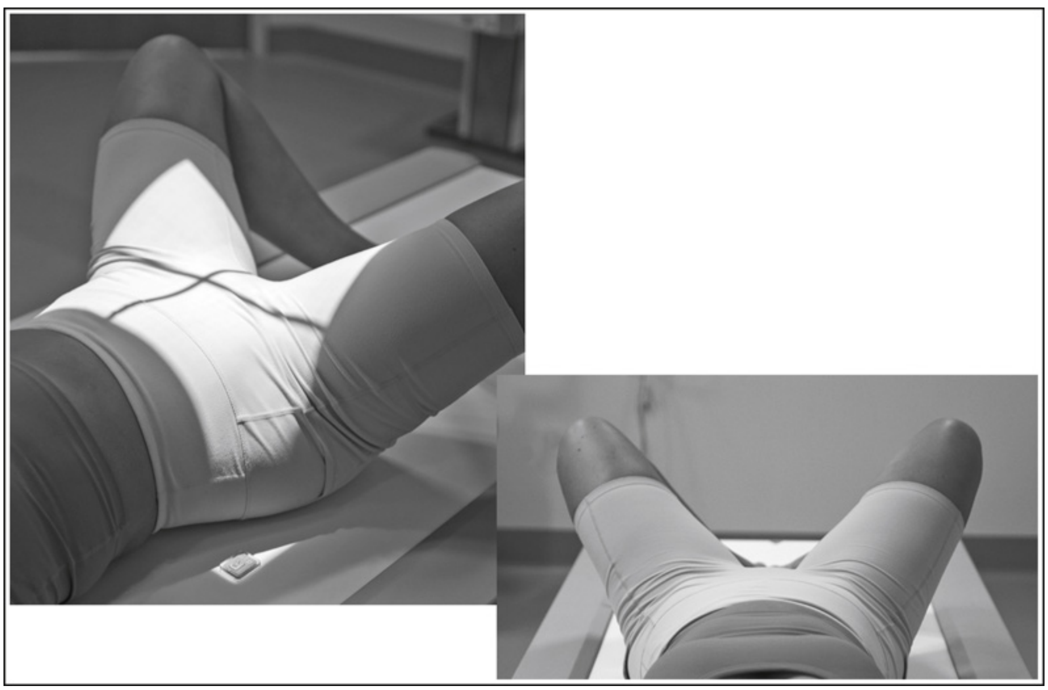


FIGURE 7.14 Proper patient positioning for AP frog-leg pelvis projection.

FIGURE 7.15 AP frog-leg pelvis projection taken with the left side of the pelvis rotated toward the IR.

How each proximal femur appears depends on the degree of femoral abduction placed on that leg. As a standard, unless the projection is ordered to evaluate hip mobility, both femurs should be abducted equally for the projection. This symmetric abduction helps prevent pelvic rotation. It may be necessary to position an angled sponge beneath the femurs to maintain the desired femoral abduction. Use a femoral skeleton bone to understand how leg abduction determines the visualization of the femoral neck and the position of the greater trochanter.

FIGURE 7.16 Proper knee and hip flexion for an AP frog-leg pelvis projection; 60 to 70 degrees from the IR.

Insufficient Femoral Abduction

If the femoral shafts are abducted less than 45 degrees with the IR (**Fig. 7.19**) for an AP frog-leg pelvis, the resulting projection will demonstrate the femoral necks without foreshortening and the proximal greater trochanters at about or at the same transverse level as the lesser trochanters (**Fig. 7.20**).

FIGURE 7.17 AP frog-leg pelvis projection taken with insufficient knee and hip flexion.

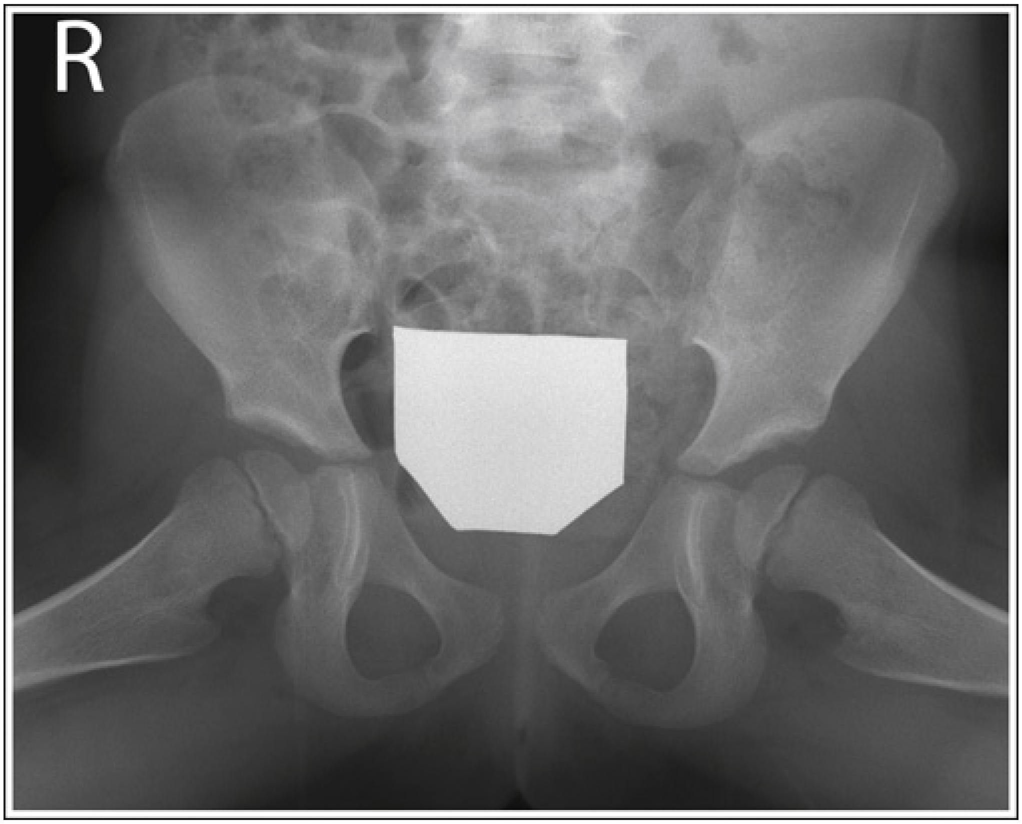


FIGURE 7.18 AP frog-leg hip with excessive knee and hip flexion (<60 degrees from the IR).

Excessive Femoral Abduction

If the femoral shafts are abducted greater than 45 degrees for an AP frog-leg pelvis (**Fig. 7.21**), the resulting projection will demonstrate the proximal femoral shafts with minimal foreshortening, the proximal greater trochanters at approximately or at the same transverse level as the femoral heads, and the femoral necks on end (**Fig. 7.22**).

FIGURE 7.19 Femurs in only slight abduction (20 degrees from vertical).

Projections to Determine Hip Mobility

When AP and AP frog-leg (mediolateral) projections are taken to determine hip mobility, the CR is centered at a level 1 inch (2.5 cm) superior to the pubis symphysis (**Figs. 7.23** and **7.24**). This lower centering for the AP will place the hip joints at the center of the projection.

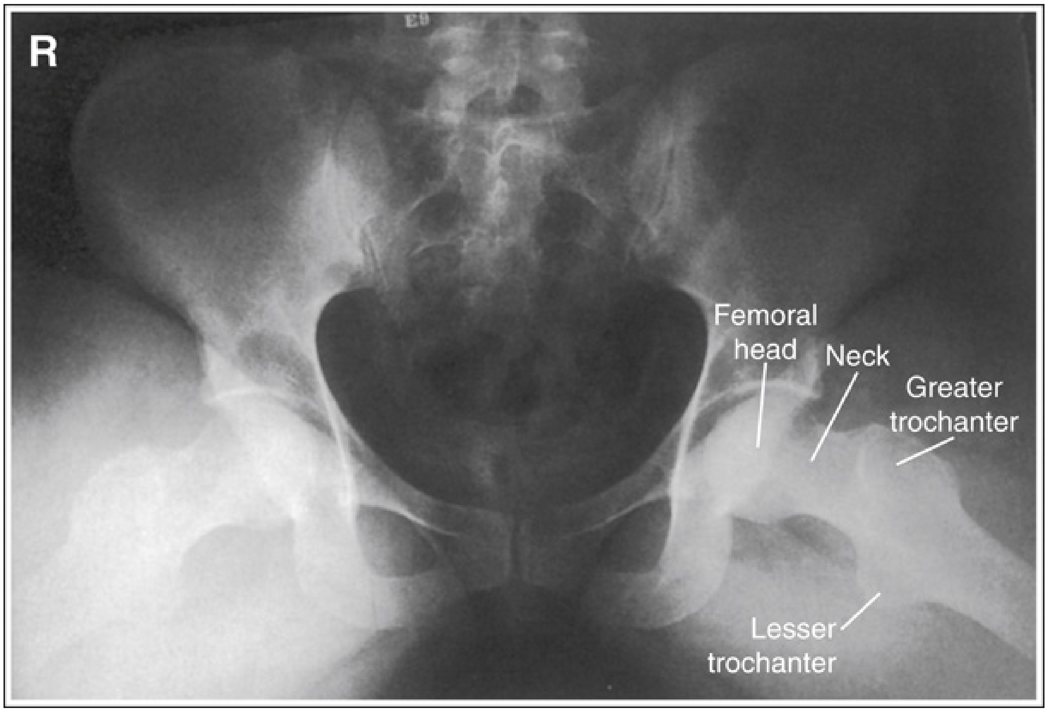


FIGURE 7.20 AP frog-leg pelvis projection taken with the femoral shafts abducted to a 60- to 70-degree angle with the IR.

FIGURE 7.21 Femurs in maximum abduction (20 degrees from the IR).

FIGURE 7.22 AP frog-leg pelvis projection taken with the femoral shafts abducted to a 20-degree angle with the IR.

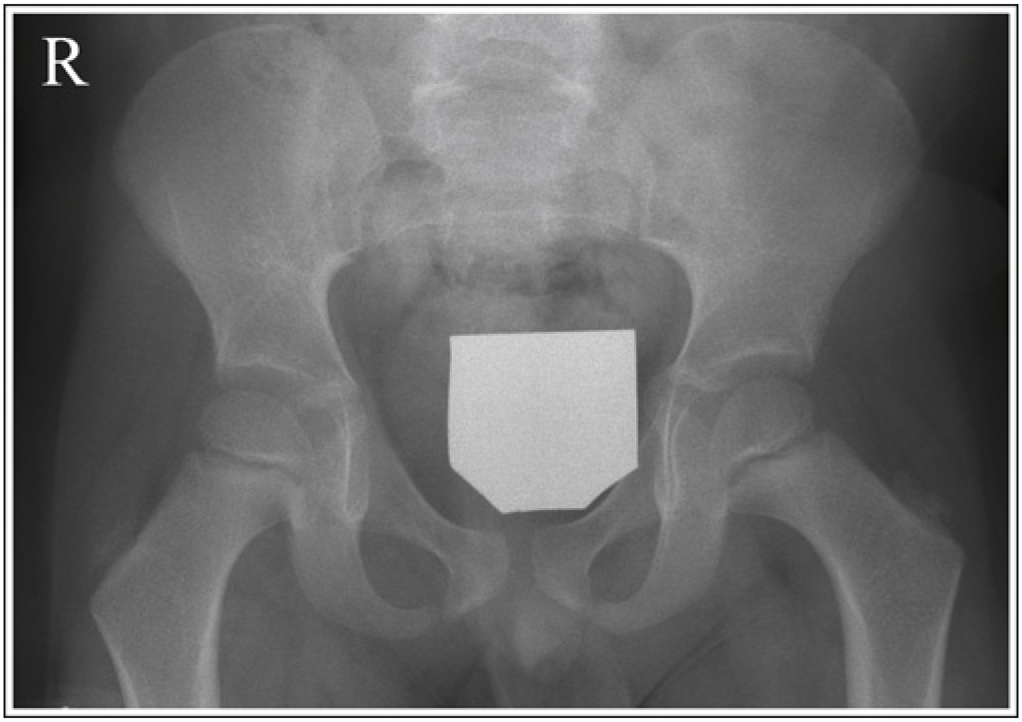


FIGURE 7.23 AP pediatric pelvis projection with accurate positioning taken to demonstrate hip joint mobility.

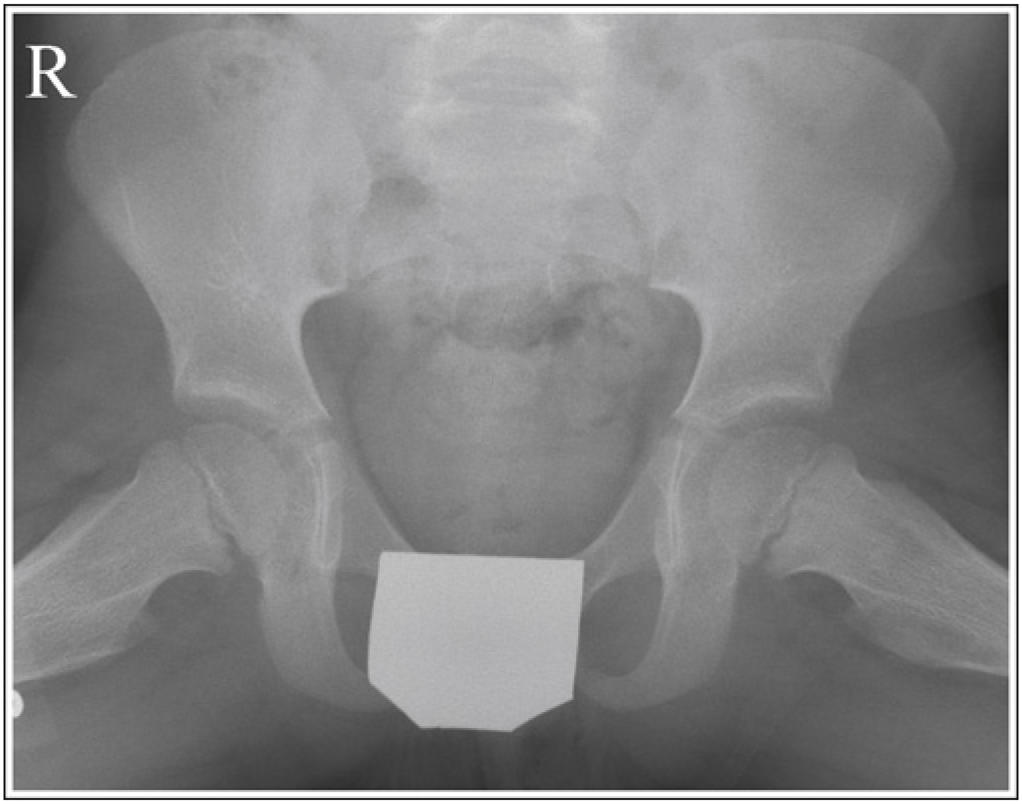


FIGURE 7.24 AP pediatric frog-leg pelvis projection taken to demonstrate hip joint mobility.

AP Frog-Leg Pelvis Analysis Practice

IMAGE 7.2

Analysis

The proximal greater trochanters are at the same level as the femoral heads and the femoral necks are foreshortened. The femurs were abducted more than 45 degrees with the imaging table.

Correction

Decrease the degree of femoral abduction to 45 degrees.

Pelvis (Acetabulum): AP Oblique Projection (Judet Method)

See **Table 7.5** and Figures **7.25**–**7.28**

Insufficient Pelvis Obliquity

Side-up Hip: If the pelvis was rotated less than 45 degrees the iliac wing is not demonstrated on end, the iliac body is without superimposition, and the lateral edge of the sacrum is not touching the pelvic brim (**Fig. 7.29**).

Side-down Hip: If the pelvis was rotated less than 45 degrees the obturator foramen is demonstrated, and the medial and lateral sides are not touching (**Fig. 7.29**).

Excessive Pelvis Obliquity

Side-up Hip: If the pelvis was rotated more than 45 degrees with the IR, the resulting AP oblique projection demonstrates the pelvic brim and ilium superimposing the sacrum and the upside pubic symphysis superimposing the downside ischium (**Fig. 7.30**).

Side-down Hip: If the pelvis was rotated more than 45 degrees with the IR the obturator foramen is not demonstrated, and the pubis and ischium are superimposed (**Fig. 7.30**).

TABLE 7.5

AP, Anteroposterior; *ASIS,* anterior superior iliac spine; *CR,* central ray; *IR,* image receptor; *LPO,* left posterior oblique; *RPO,* right posterior oblique.

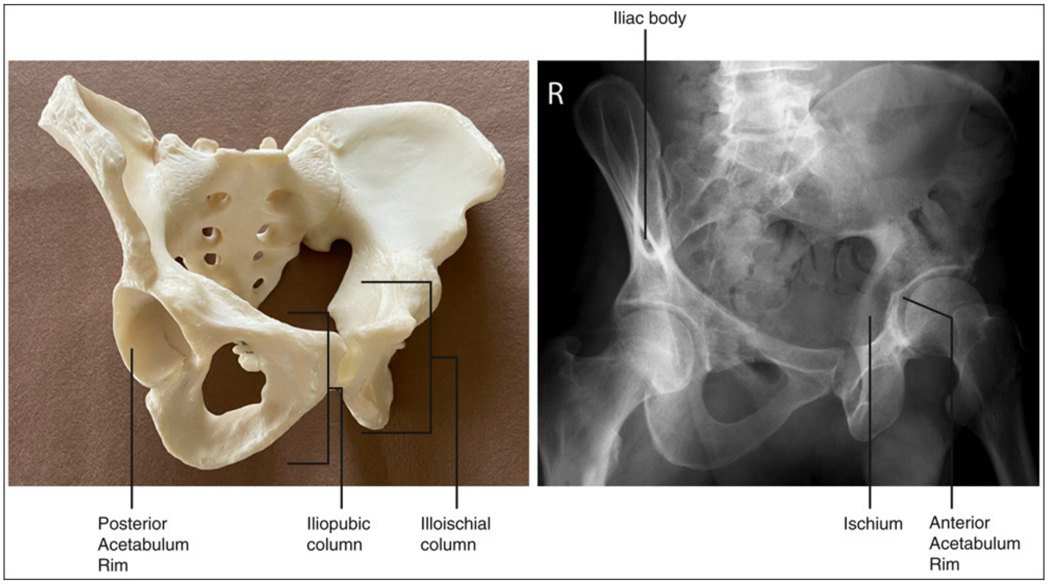


FIGURE 7.25 AP oblique pelvis projection (Judet method) with accurate positioning.

FIGURE 7.26 Proper patient positioning for AP oblique pelvis projection (Judet method).

FIGURE 7.27 AP oblique hip (side-up) projection with accurate positioning.

FIGURE 7.28 AP oblique hip (side-down) projection with accurate positioning.

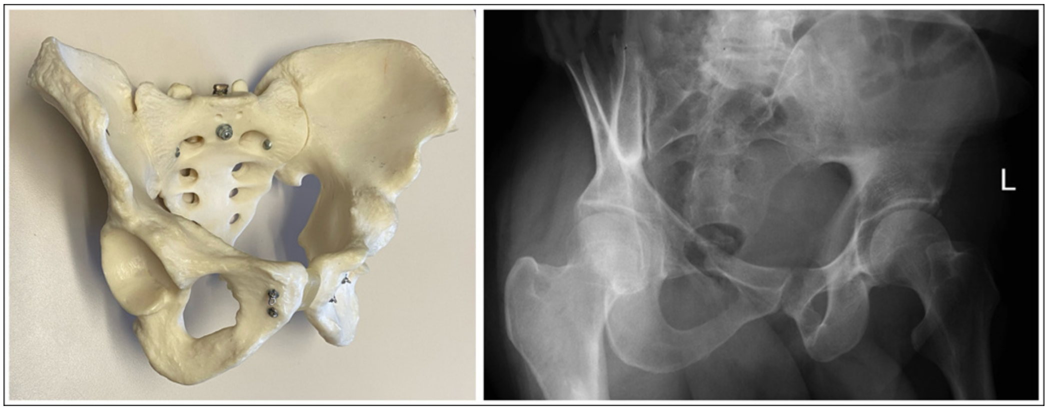


FIGURE 7.29 AP oblique pelvis projection taken with insufficient pelvis rotation.

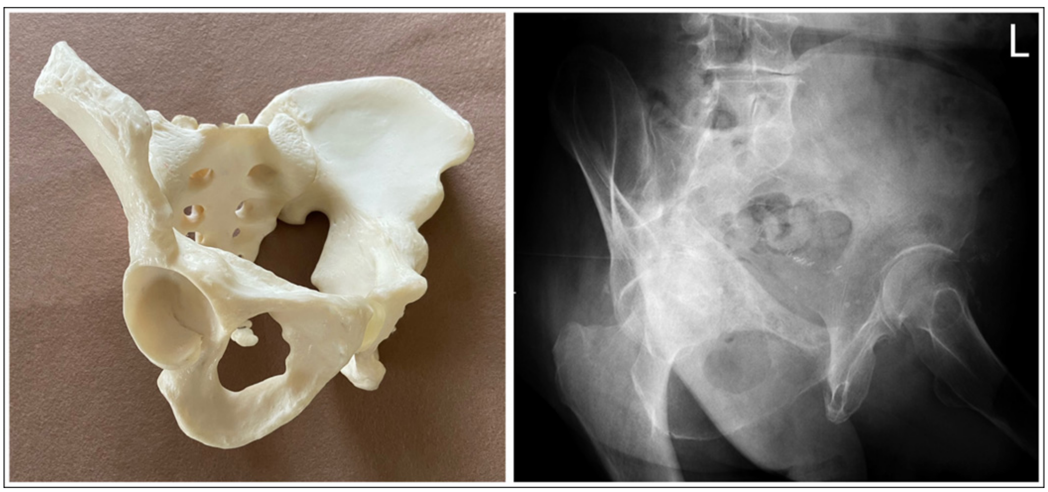


FIGURE 7.30 AP oblique pelvis projection taken with excessive pelvis rotation.

AP Oblique Pelvis Analysis Practice

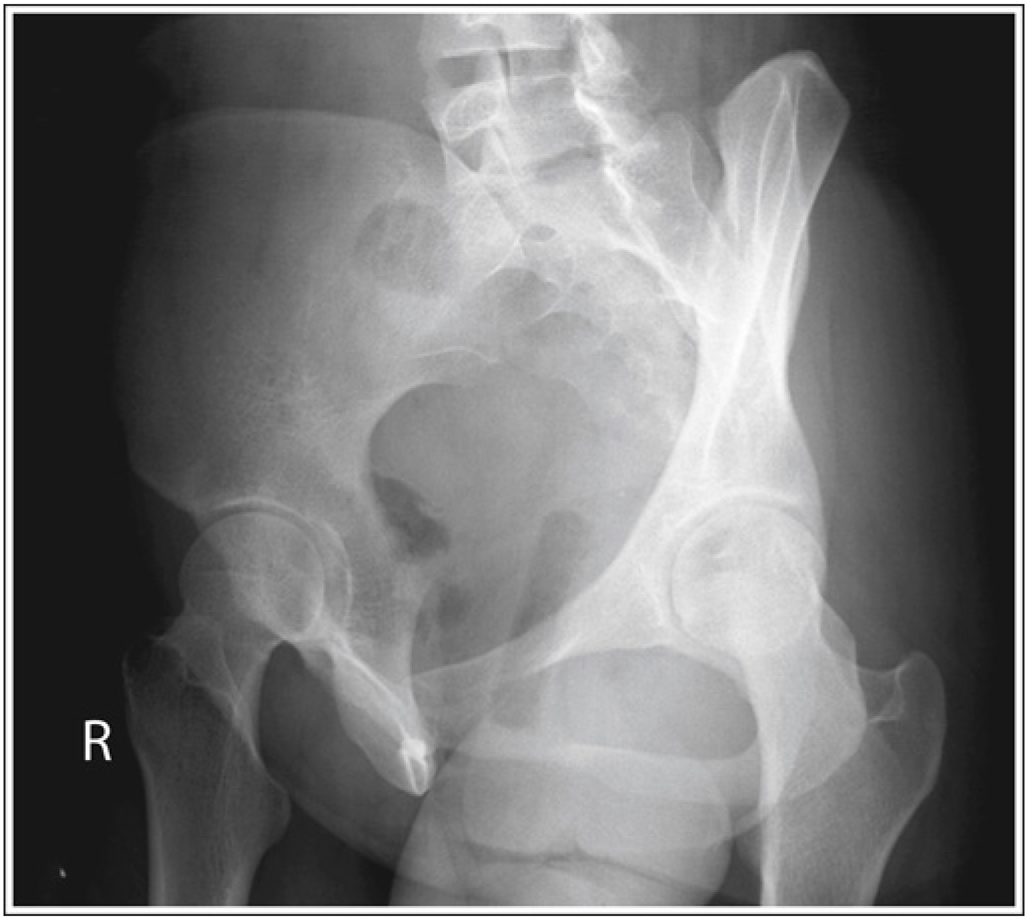


IMAGE 7.3

Analysis

The left side of the pelvic brim and ilium are superimposing the sacrum, the upside pubic symphysis superimposes the downside ischium, the left obturator is closed, and the pubis and ischium are superimposed. The pelvis was rotated more than 45 degrees.

Correction

Decrease the degree pelvis rotation until the midcoronal plane forms a 45-degree angle with the IR.

Pelvis (Anterior Pelvic Bones): AP Axial Outlet Projection (Taylor Method)

See **Table 7.6** and **Figs. 7.31** and **7.32**.

Pelvis Rotation: LPO Position

If the pelvis is rotated into an LPO position, the left ilium demonstrates less foreshortening than the right ilium, the left obturator foramen demonstrates more foreshortening than the right, and the sacrum and coccyx are rotated toward the right hip (**Fig. 7.33**).

Pelvis Rotation: RPO Position

If the pelvis is rotated into an RPO position, the right ilium demonstrates less foreshortening than the left, the right obturator foramen demonstrates more foreshortening than the left, and the sacrum and coccyx are rotated toward the left hip.

Insufficient CR Angulation

If the AP axial outlet pelvis projection is taken with less than the required cephalic CR angulation, the pubic bones superimpose the fifth sacral segment and coccyx, and the ischial spines are superior to the obturator foramina (**Fig. 7.34**).

Excessive CR Angulation

If the AP axial outlet pelvis projection is taken with more than the required cephalic CR angulation, the pubic bones are superimposing the first and second sacral segments and the ischial spines are in the lower half of the obturator foramina (**Fig. 7.35**).

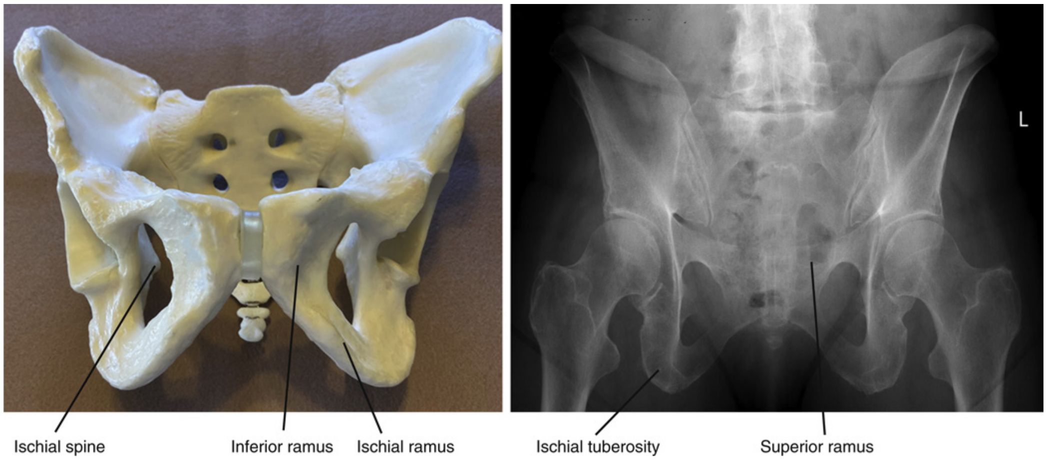


FIGURE 7.31 AP axial outlet pelvis projection (Taylor method) with accurate positioning.

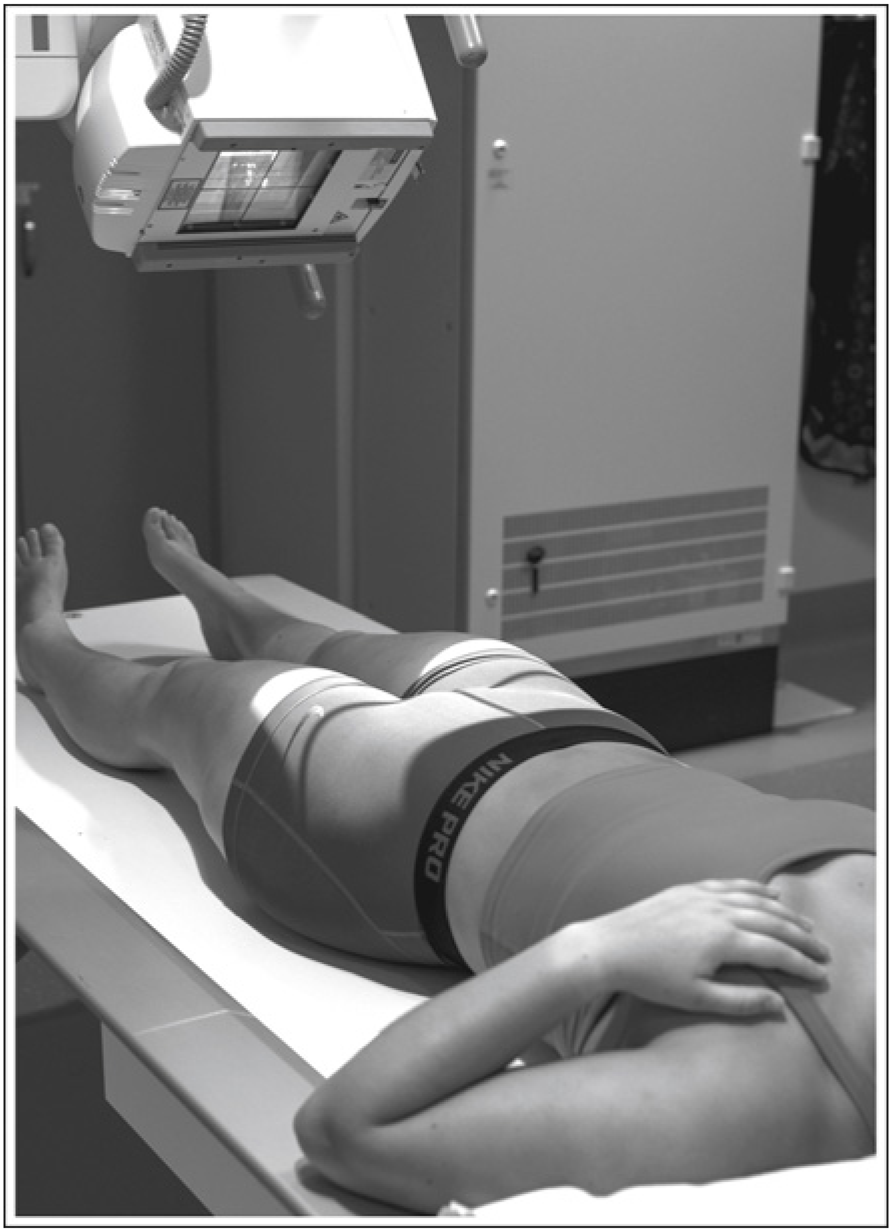


FIGURE 7.32 Proper patient positioning for AP axial outlet pelvis projection (Taylor method).

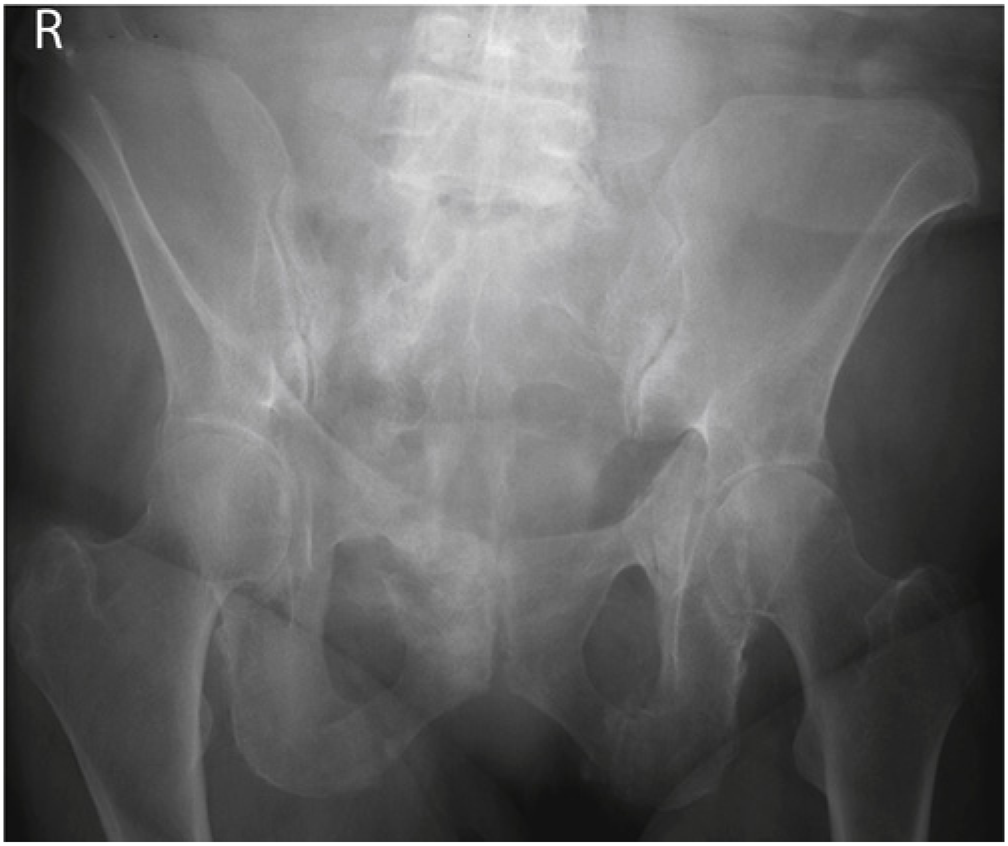


FIGURE 7.33 AP axial outlet pelvis projection taken with the pelvis rotated toward the left side (LPO position).

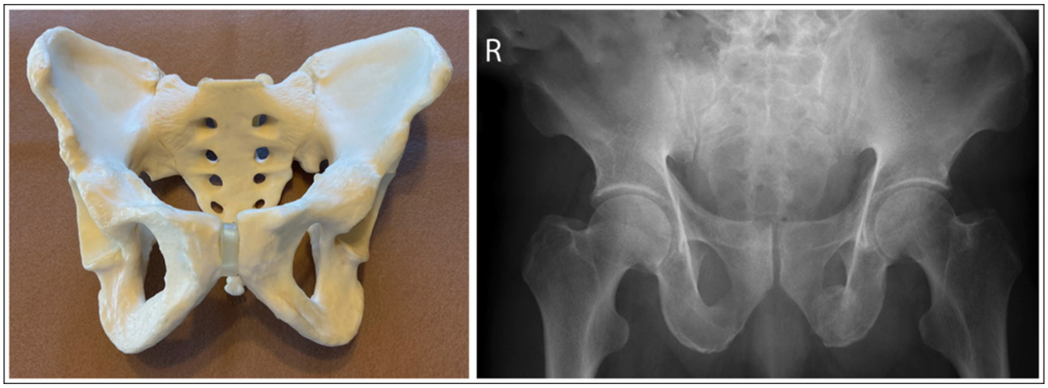


FIGURE 7.34 AP axial outlet pelvis projection obtained with insufficient cephalic CR angulation.

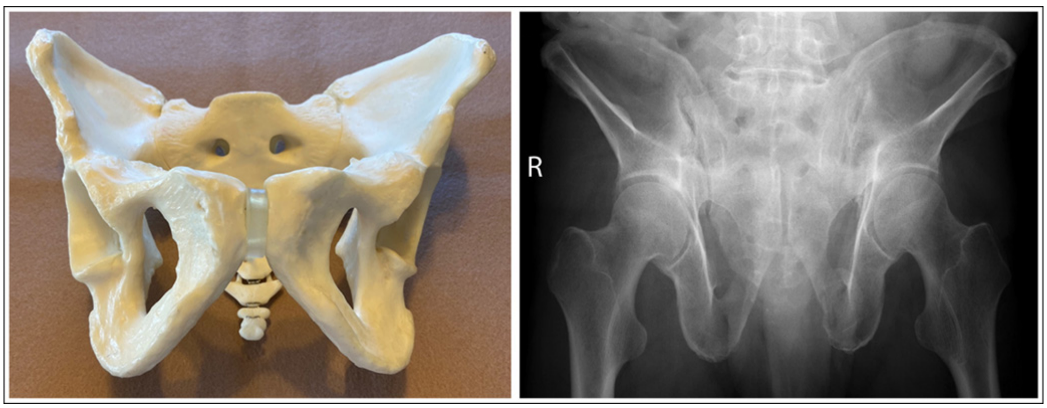


FIGURE 7.35 AP axial outlet pelvis projection obtained with excessive cephalic CR angulation.

TABLE 7.6

AP, Anteroposterior; *ASIS,* anterior superior iliac spine; *CR,* central ray; *IR,* image receptor.

AP Axial Outlet Pelvis Analysis Practice

IMAGE 7.4

Analysis

The pubic bones are superimposing the second and third sacral segments and the superior rami superimpose the inferior alae. The CR was angled too cephalically.

Correction

Decrease the degree of cephalic CR angulation.

IMAGE 7.5

Analysis

The pubic bones are superimposing the coccyx, and ischial spines are superior to the obturator foramina. The CR was not angled enough.

Correction

Increase the degree of CR cephalic angulation.

Pelvis (Anterior Pelvis Bones): Superoinferior Axial Inlet Projection (Bridgeman Method)

See **Table 7.7** and **Figs. 7.36** and **7.37**.

Insufficient CR Angulation

If the superoinferior axial inlet pelvis projection is taken with less than a 40-degree caudal CR angulation, the superior pubic rami are seen superior to the inferior pubic rami, and the obturator foramina are demonstrated (**Fig. 7.38**).

Excessive CR Angulation

If the superoinferior axial inlet pelvis projection is taken with more than a 40-degree caudal CR angulation, the superior pubic rami are seen inferior to the inferior pubic rami (**Fig. 7.39**).

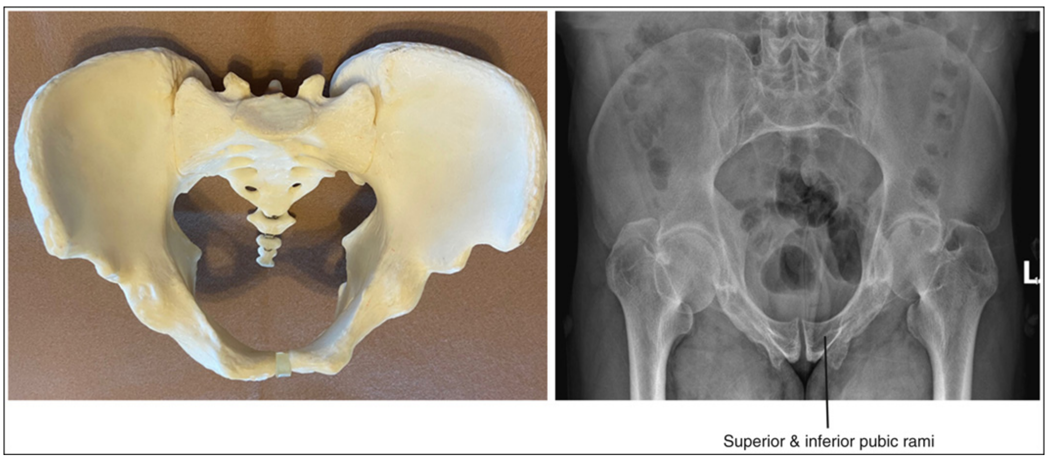


FIGURE 7.36 Superoinferior axial inlet pelvis projection (Bridgeman method) with accurate positioning.

TABLE 7.7

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

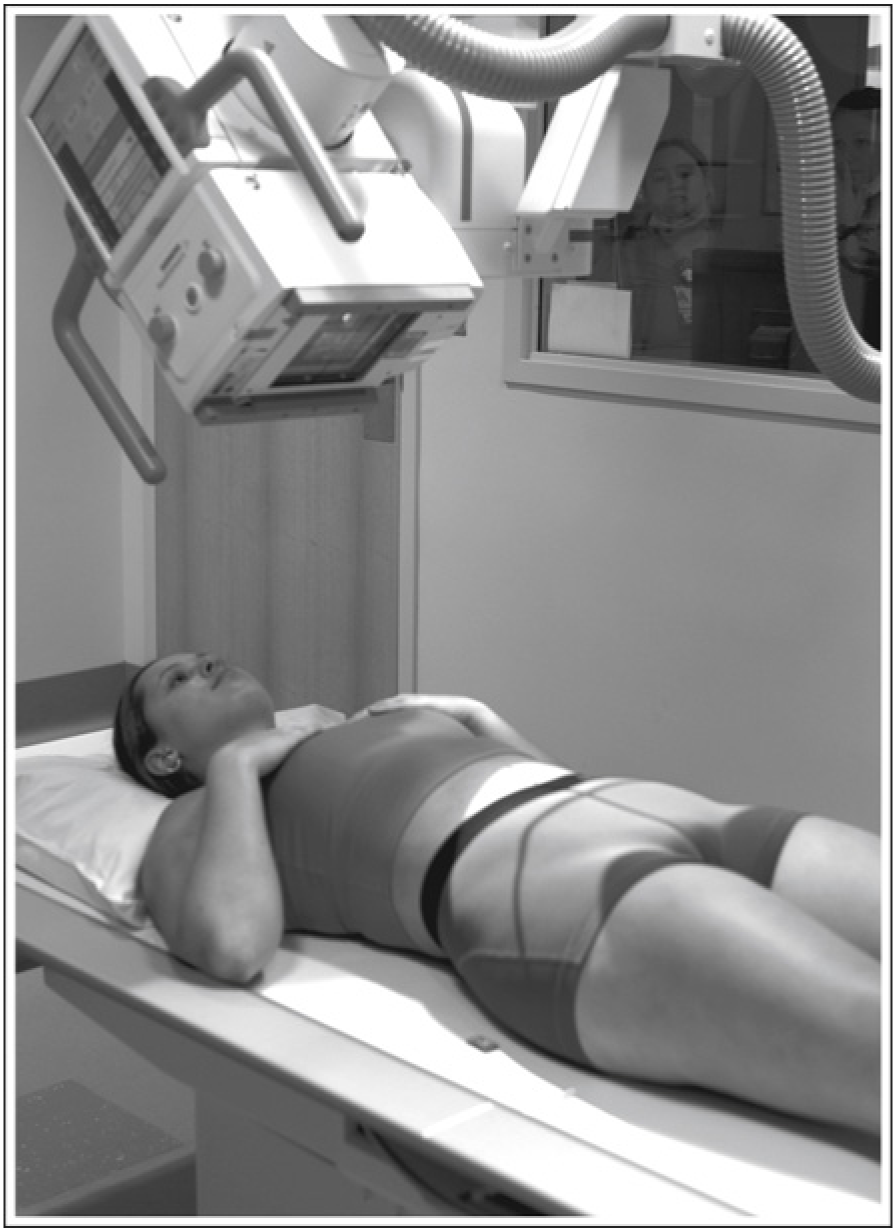


FIGURE 7.37 Proper patient positioning for superoinferior axial inlet pelvis projection (Bridgeman method).

Superoinferior Axial Inlet Pelvis Analysis Practice

IMAGE 7.6

Analysis

The superior pubic rami are superior to the inferior pubic rami and the obturator foramina are seen. The CR was not angled caudally enough.

Correction

Increase the degree of caudal CR angulation.

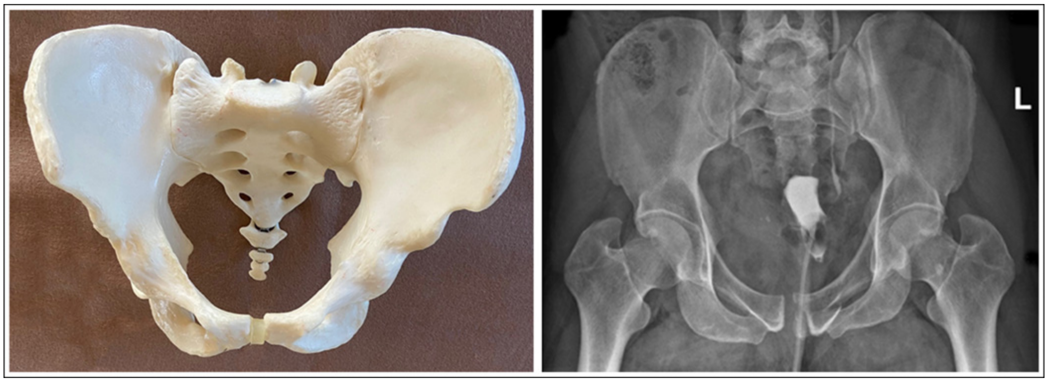


FIGURE 7.38 Superoinferior axial inlet pelvis projection obtained with the pelvis rotated toward the right side and insufficient caudal CR angulation.

Hip: AP Projection

See **Table 7.8** and **Figs. 7.40** and **7.41**.

Pelvis Rotated Toward Affected Hip

If the pelvis was rotated toward the affected hip, the ischial spine is demonstrated without pelvic brim superimposition, the sacrum and coccyx are not aligned with the pubis symphysis but are rotated away from the affected hip, and the obturator foramen demonstrates increased foreshortening (**Fig. 7.42**).

Pelvis Rotated Away From Affected Hip

If the pelvis has been rotated away from the affected hip, the ischial spine is not aligned with the pelvic brim but is demonstrated closer to the acetabulum, the sacrum and coccyx are not aligned with the pubis symphysis but are rotated toward the aff ected hip, and the obturator foramen demonstrates decreased foreshortening (**Fig. 7.43**).

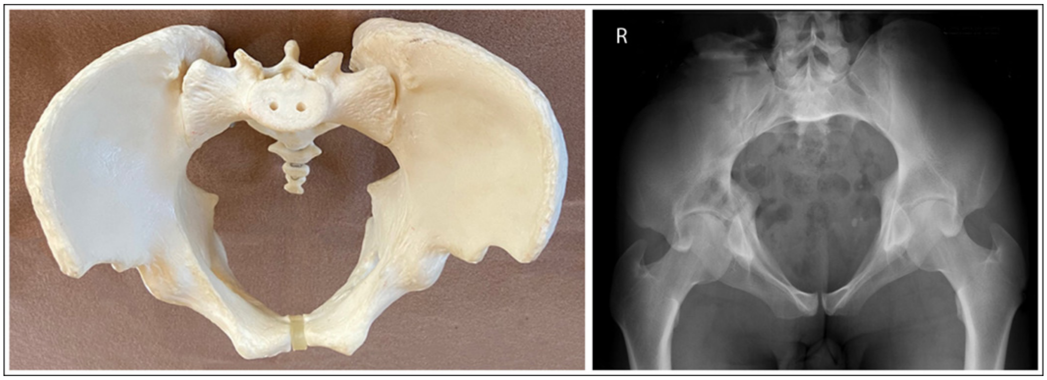


FIGURE 7.39 Superoinferior axial inlet pelvis projection obtained with excessive caudal CR angulation.

TABLE 7.8

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

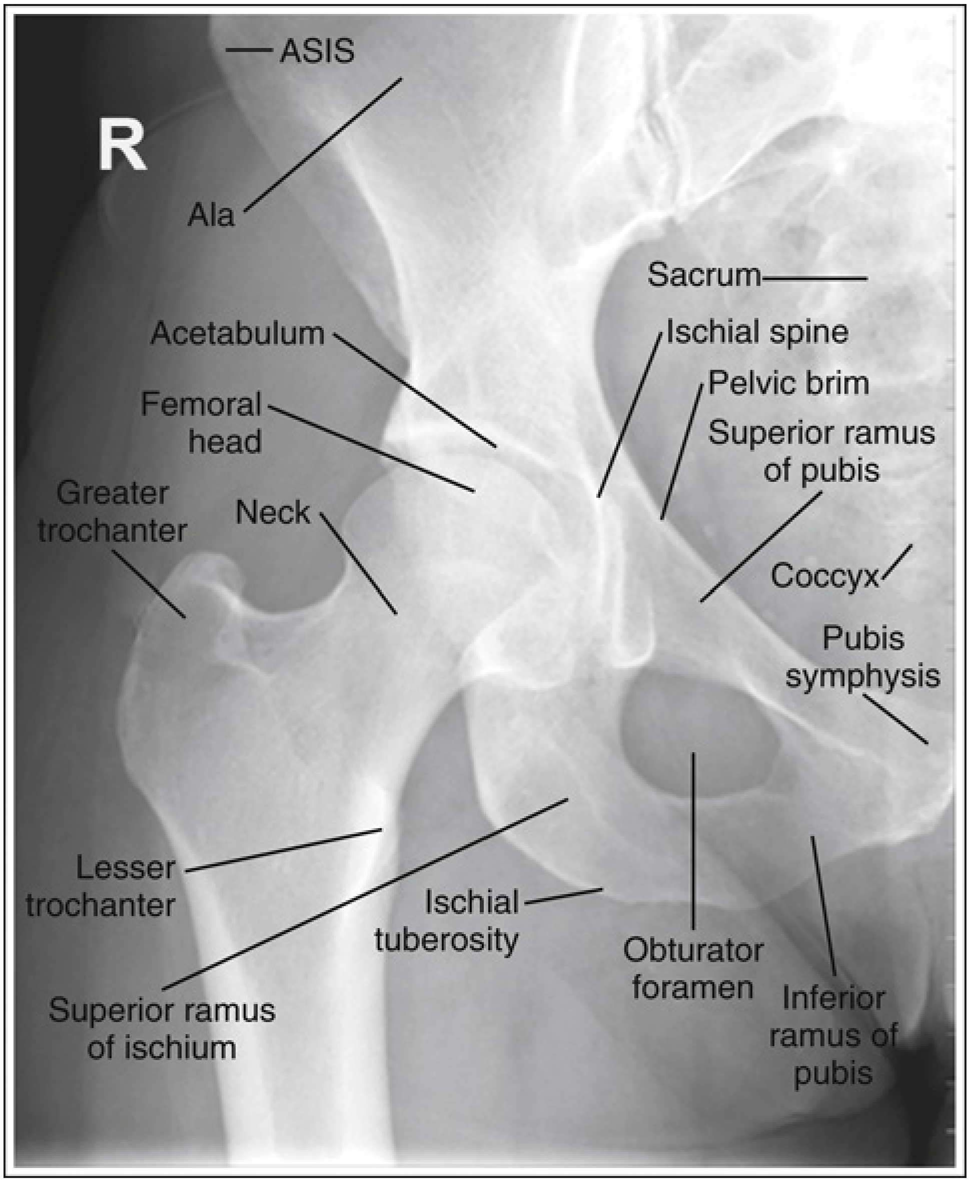


FIGURE 7.40 AP hip projection with accurate positioning.

FIGURE 7.41 Proper patient positioning for AP hip projection.

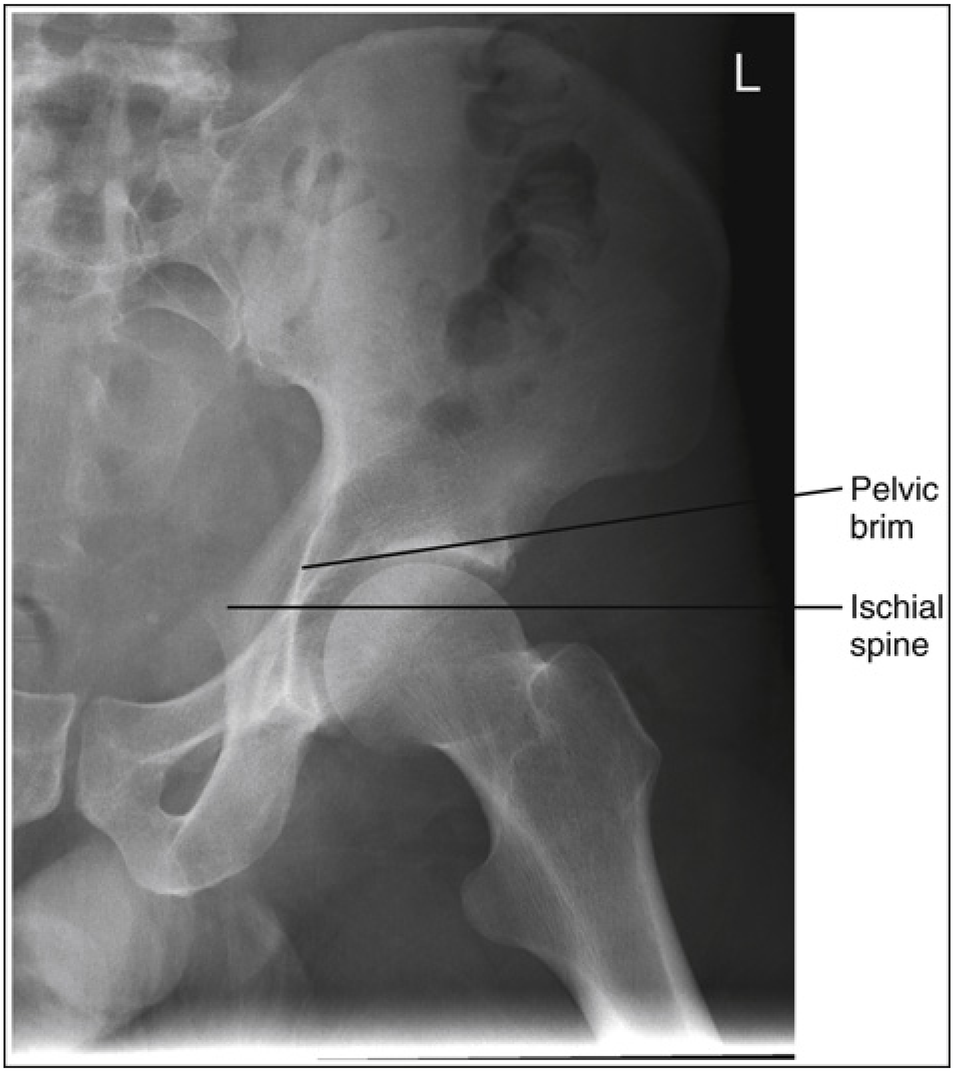


FIGURE 7.42 AP hip projection taken with the patient rotated toward the affected hip.

External Leg Rotation

If the leg is externally rotated enough to position the foot at a 45-degree angle, with the femoral epicondyles at a 60- to 65-degree angle with the IR, the femoral neck is demonstrated on end and the lesser trochanter is demonstrated in profile (**Figs. 7.44** and **7.45**).

Insufficient Internal Leg Rotation

If the leg is positioned with the foot placed vertically, with the femoral epicondyles at approximately a 15- to 20-degree angle with the IR, the lesser trochanter is demonstrated in partial profile and the femoral neck is only partially foreshortened (**Fig. 7.46**).

Proximal Femur or Femoral Neck Fracture

If the leg is not internally rotated when a proximal femur or femoral neck fracture is in question, the resulting AP hip projection demonstrates the affected femoral neck with some degree of foreshortening and the lesser trochanter without femoral shaft superimposition (**Fig. 7.47**).

Hip Dislocation

When an AP hip projection is requested and a hip dislocation is suspected, the affected leg should not be internally rotated but left as it is. The resulting projection will demonstrate the femoral head superior to the acetabulum (**Fig. 7.48**).

FIGURE 7.43 AP hip projection taken with the patient rotated away from the affected hip.

FIGURE 7.44 Poor foot rotation.

FIGURE 7.45 AP hip projection taken with the leg externally rotated to position the foot at a 45-degree angle with IR.

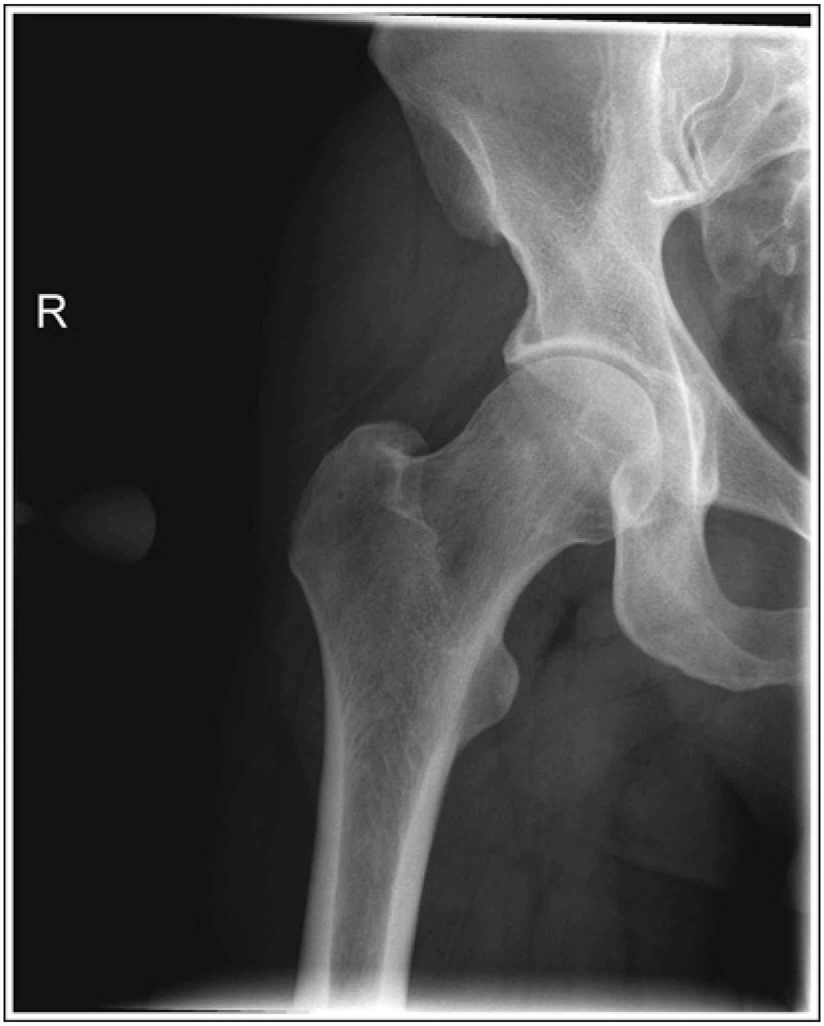


FIGURE 7.46 AP hip projection taken with the foot placed vertically and the femoral epicondyles at a 15- to 20-degree angle with the IR.

FIGURE 7.47 AP hip projection taken of a patient with a femoral neck fracture.

FIGURE 7.48 AP hip projection demonstrating a left hip dislocation on a patient with a total hip replacement.

FIGURE 7.49 AP hip projection on patient with orthopedic apparatus.

Hip and Proximal Femur Orthopedic Apparatuses

When an AP hip projection is requested and the patient has had an orthopedic apparatus placed in the hip joint or proximal femur, the entire apparatus is to be included on the resulting projection (**Fig. 7.49**). This may require a more distal placement of the IR and more distal CR centering.

Localizing the Femoral Head and Neck

Two methods are used to localize the femoral head and neck for hip projections, with the second method being the preferred method when imaging the obese patient. To use the first method to place the femoral head in the center of the exposure field, center the CR 1.5 inches (4 cm) distal to the midpoint of a line connecting the ASIS and pubis symphysis (**Fig. 7.50**). To place the femoral neck in the center of the exposure field, center the CR 2.5 inches (6.25 cm) distal to the midline of a line connecting the ASIS and pubis symphysis. For the second method, position the CR 1 to 2 inches (2.5 to 5 cm) medial and 3 to 4 inches (9 to 10 cm) distal to the ASIS (see **Fig. 7.50**).

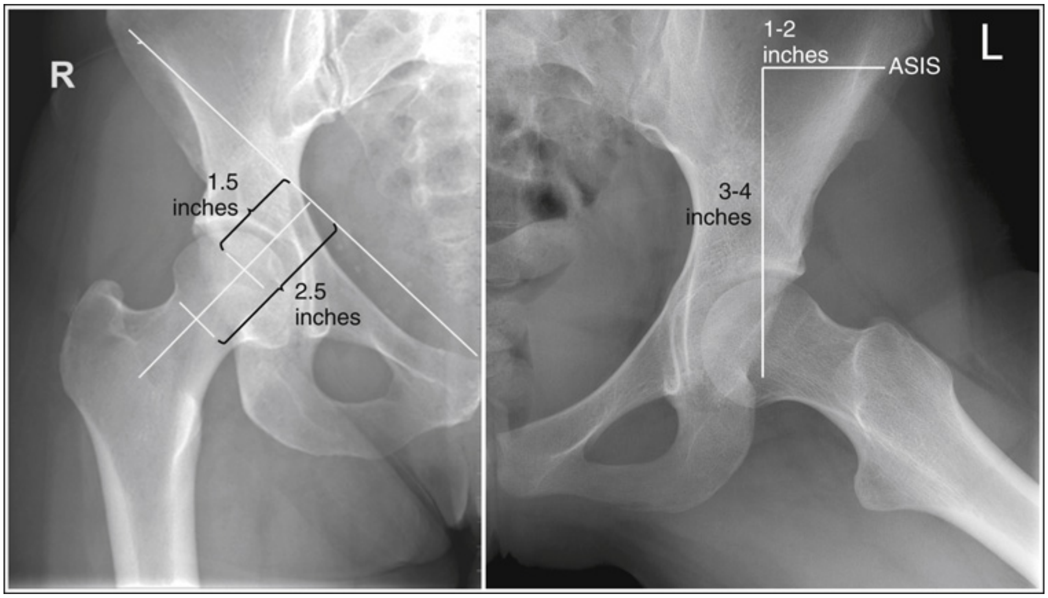


FIGURE 7.50 Localization of hip joint and femoral neck.

AP Hip Analysis Practice

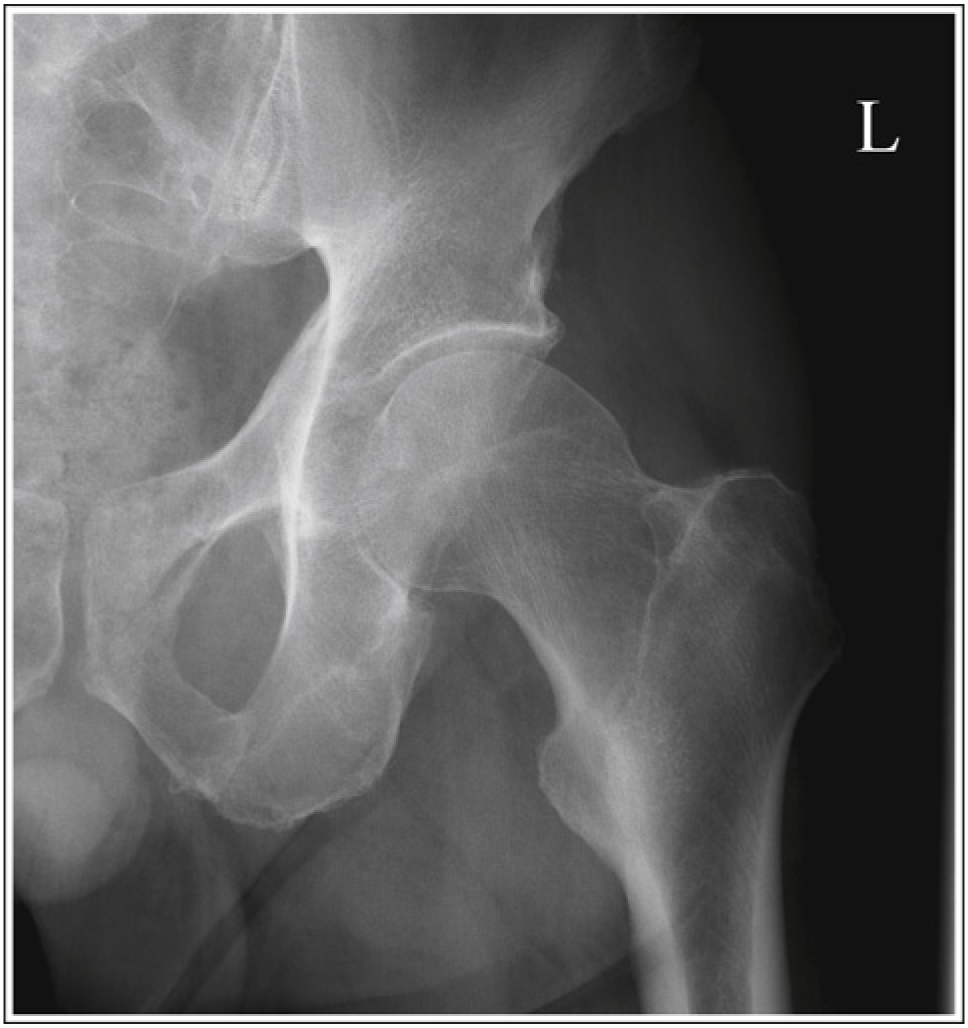


IMAGE 7.7

Analysis

The femoral neck is partially foreshortened, and the lesser trochanter is demonstrated in profile. The leg was externally rotated.

Correction

Internally rotate the leg until the foot is angled 15 to 20 degrees from vertical and the femoral epicondyles are positioned parallel with the IR.

IMAGE 7.8

Analysis

The ischial spine is demonstrated without pelvic brim superimposition, the sacrum and coccyx are not aligned with the pubis symphysis but are rotated away from the affected hip, and the obturator foramen demonstrates increased foreshortening. The pelvis was rotated toward the affected hip. The femoral neck is foreshortened, and the lesser trochanter is demonstrated in profile. The leg was externally rotated.

Correction

Rotate the pelvis away from the affected hip until the ASISs are positioned at equal distances from the IR. Internally rotate the leg until the foot is angled 15 to 20 degrees from vertical and the femoral epicondyles are positioned parallel with the IR.

Hip: AP Frog-Leg (Mediolateral) Projection (Modified Cleaves Method)

See **Table 7.9** and **Figs. 7.51** and **7.52**.

Pelvis Rotated Toward the Affected Hip

If the pelvis was rotated toward the affected hip, the ischial spine is demonstrated without pelvic brim superimposition, the sacrum and coccyx are not aligned with the pubis symphysis but are rotated away from the affected hip, and the obturator foramen demonstrates increased foreshortening (**Fig. 7.53**).

Pelvis Rotated Away From the Affected Hip

If the pelvis is rotated away from the affected hip, the ischial spine is not aligned with the pelvic brim but is demonstrated closer to the acetabulum, the sacrum and coccyx are not aligned with the pubis symphysis but are rotated toward the affected hip, and the obturator foramen demonstrates decreased foreshortening (**Fig. 7.54**).

Insufficient Knee and Hip Flexion

If the knee and hip are not flexed enough to place the femur at a 60- to 70-degree angle with the IR (**Fig. 7.57**), the greater trochanter is demonstrated in partial profile laterally (see **Figs. 7.53** and **7.55**).

Excessive Knee and Hip Flexion

If the knee and hip are flexed too much, placing the femur at an angle greater than 60 to 70 degrees with the IR, the posterior aspect of the greater trochanter is demonstrated medially and obscures the less trochanter (**Fig. 7.56**).

Insufficient Femoral Abduction

If the femoral shaft is abducted less than 45 degrees with the IR, the femoral neck demonstrates decreased foreshortening, and the proximal greater trochanter is close to or at the same transverse level as the lesser trochanter (**Fig. 7.58**).

Excessive Femoral Abduction

If the femoral shaft is abducted greater than 45 degrees (**Fig. 7.59**), the proximal femoral shaft is demonstrated without foreshortening, the proximal greater trochanter is at the same transverse level as the femoral head, and the femoral neck is demonstrated on end (**Fig. 7.60**).

Lauenstein and Hickey Methods

The Lauenstein and Hickey methods are modifications of the frog-leg hip projection. For these methods, the patient is positioned as described for the AP frog-leg projection with the femur flexed and abducted, except that the pelvis is rotated toward the affected hip as needed to position the femur flat against the table (**Fig. 7.61**). An acceptable projection of these methods will look like **Fig. 7.60**.

TABLE 7.9

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

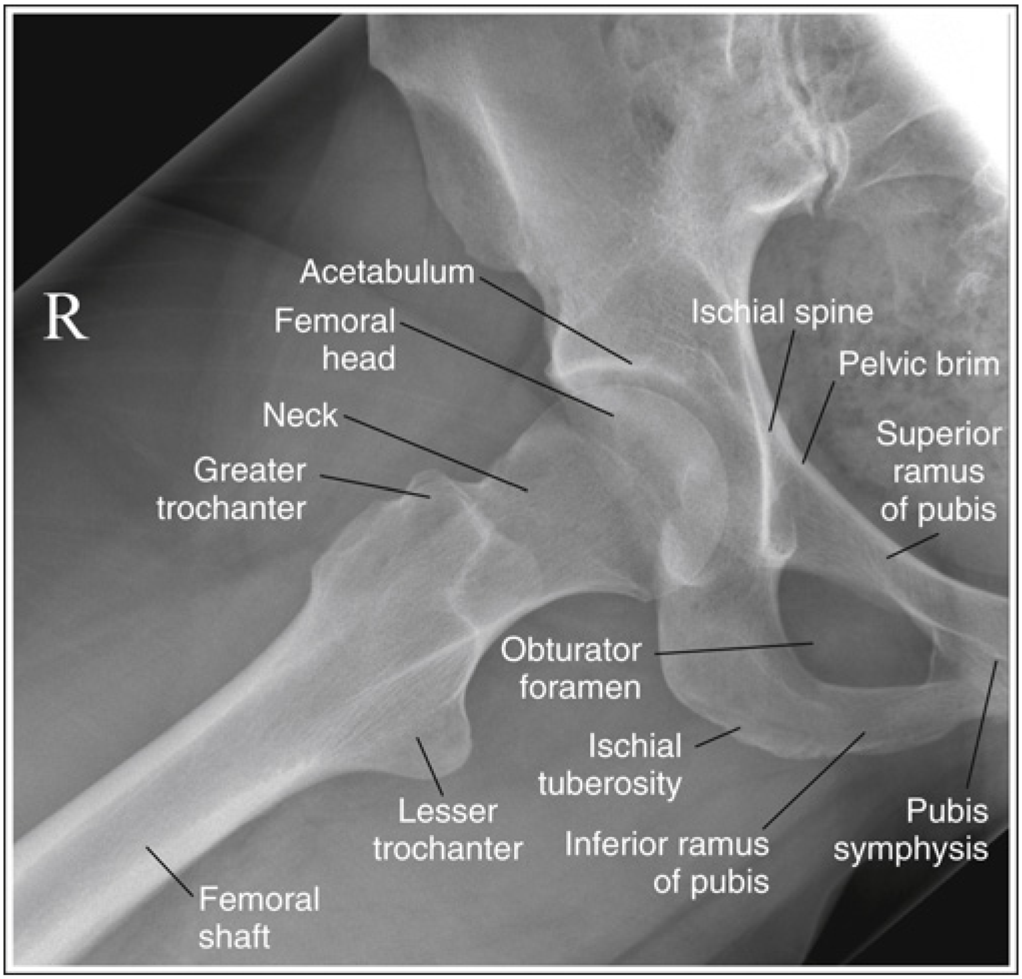


FIGURE 7.51 AP frog-leg hip projection with accurate positioning.

FIGURE 7.52 Proper patient positioning for AP frog-leg hip projection.

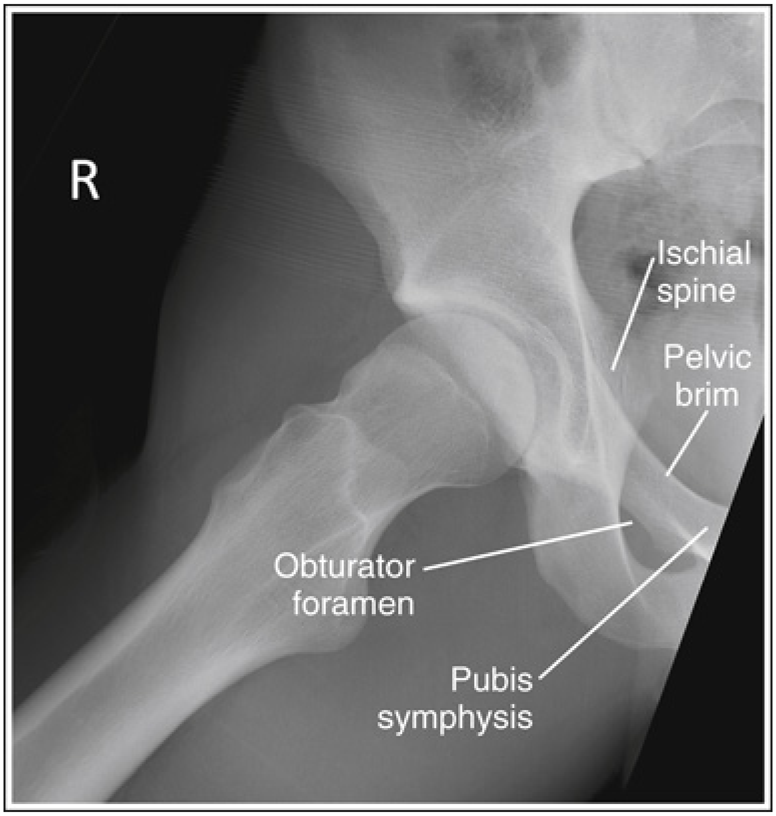


FIGURE 7.53 AP frog-leg hip projection taken with the patient rotated toward the affected hip.

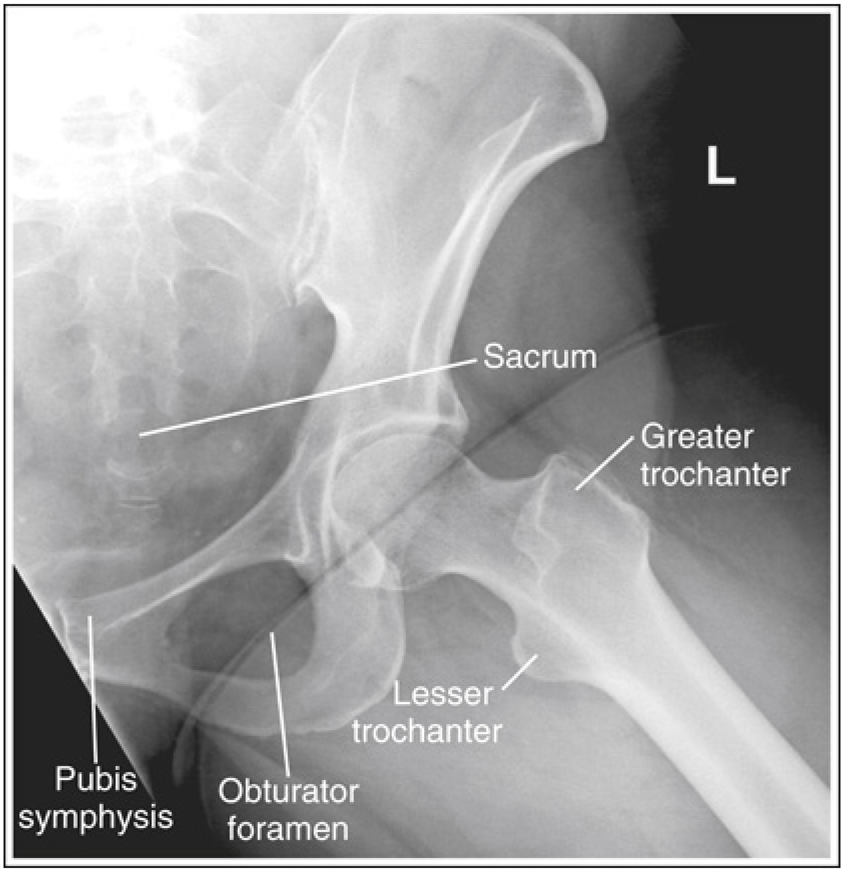


FIGURE 7.54 AP frog-leg hip projection taken with the patient rotated away from the affected hip and the knee and hip flexed less than needed to position the femur at a 60- to 70-degree angle with the IR.

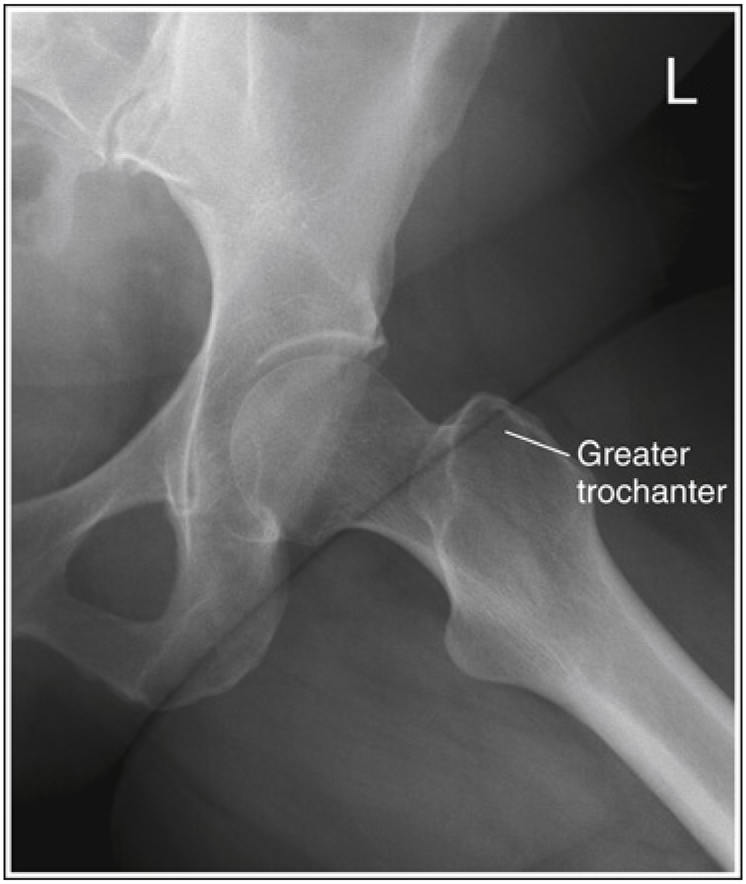


FIGURE 7.55 AP frog-leg hip projection taken with the knee and hip flexed less than needed to position the femur at a 60- to 70-degree angle with the IR.

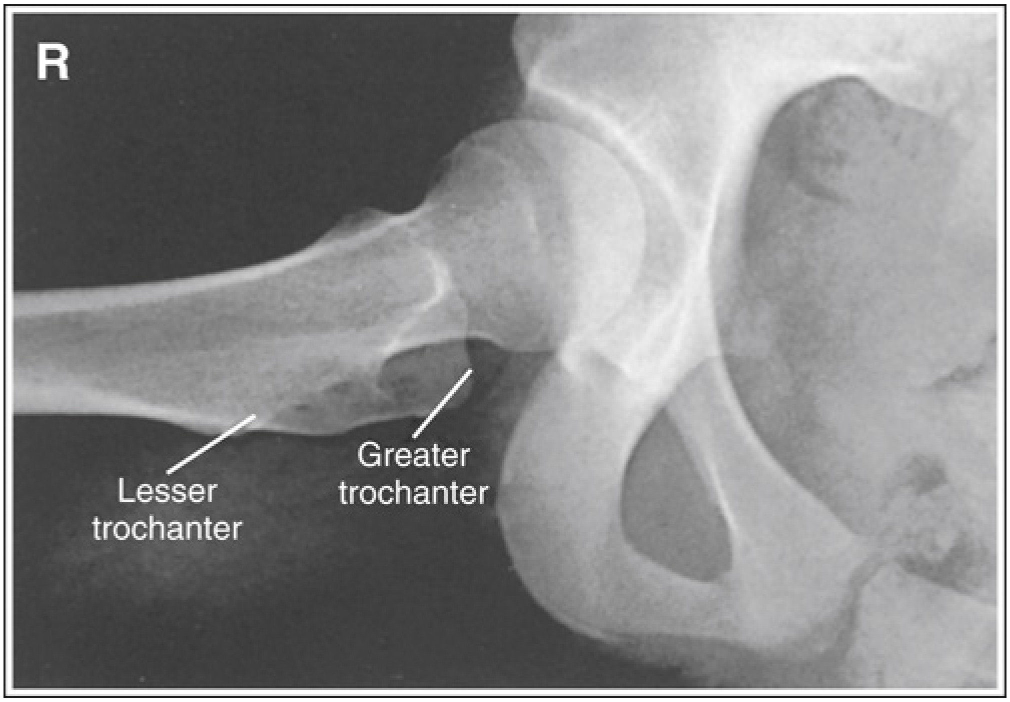


FIGURE 7.56 AP frog-leg hip projection taken with the knee and hip flexed more than needed to position the femur at a 60- to 70-degree angle with the IR.

FIGURE 7.57 Femur in only slight abduction, 20 degrees from vertical (70 degrees from the IR).

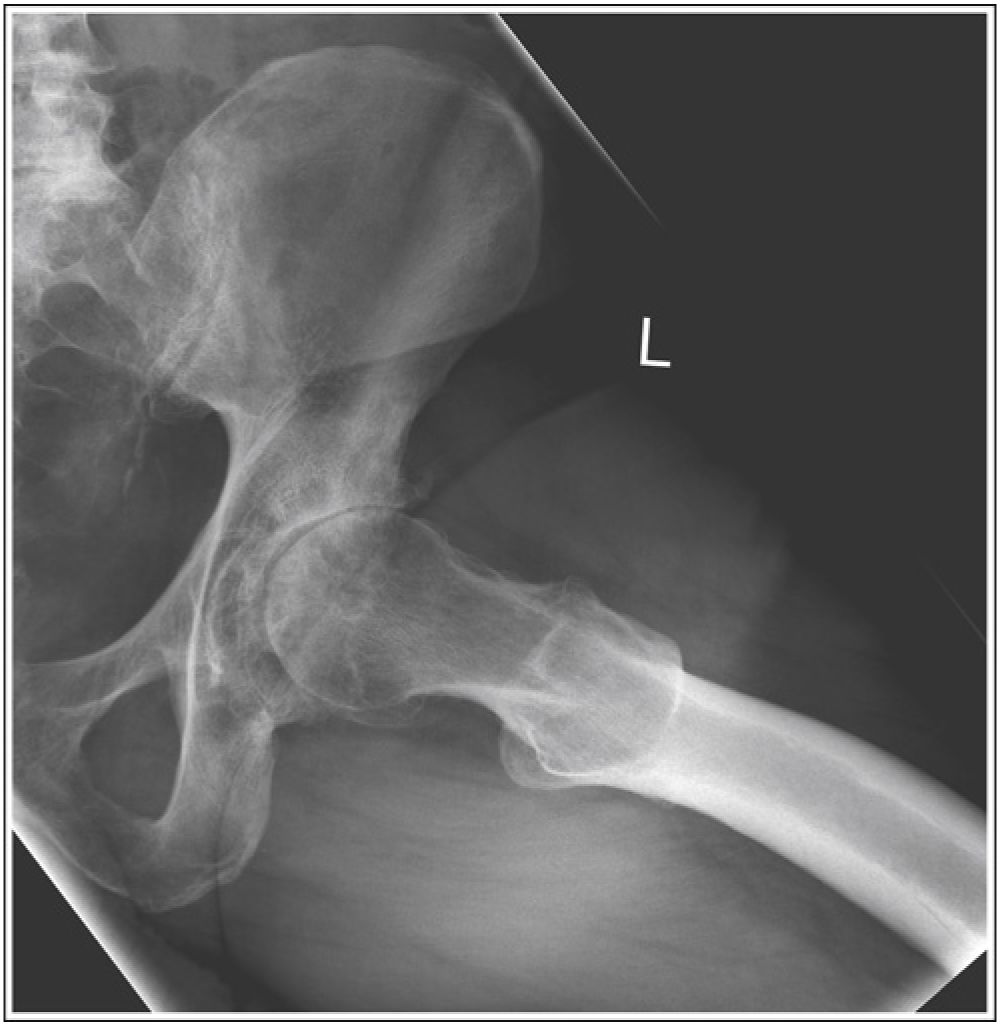


FIGURE 7.58 AP frog-leg projection taken with insufficient femoral abduction.

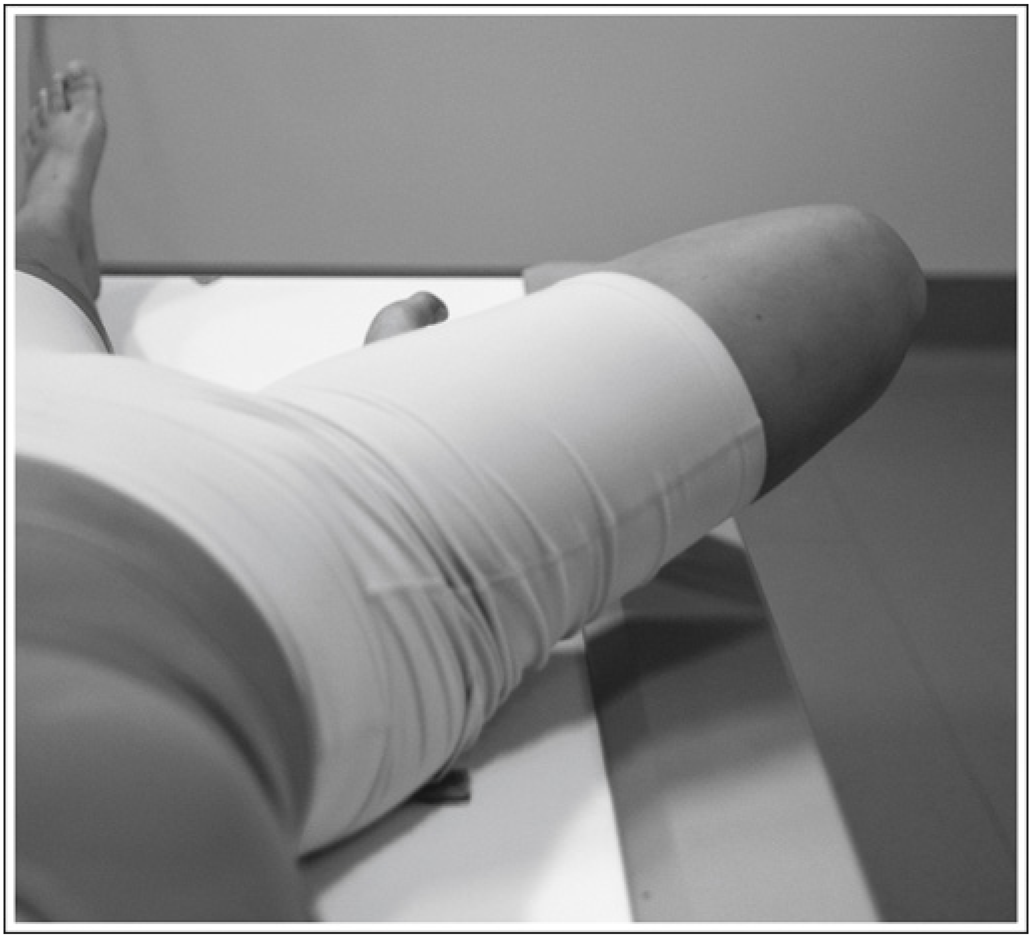


FIGURE 7.59 AP frog-leg hip projection demonstrating leg in excessive abduction.

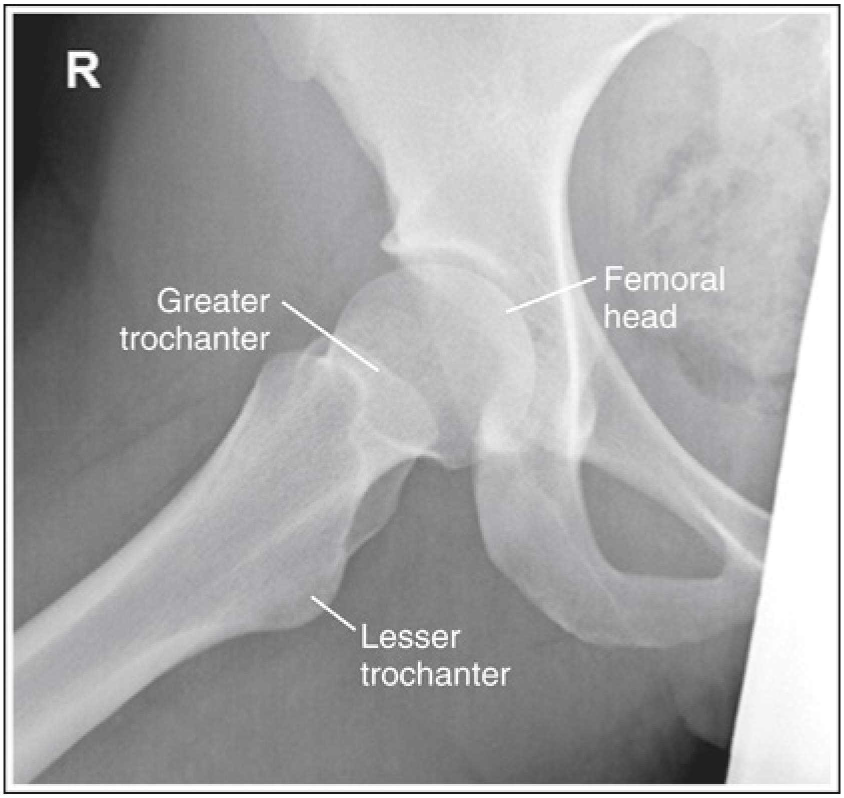


FIGURE 7.60 AP frog-leg hip projection taken with excessive femoral abduction.

FIGURE 7.61 Lateral hip projection obtained using the Lauenstein and Hickey methods.

AP Frog-Leg Hip Analysis Practice

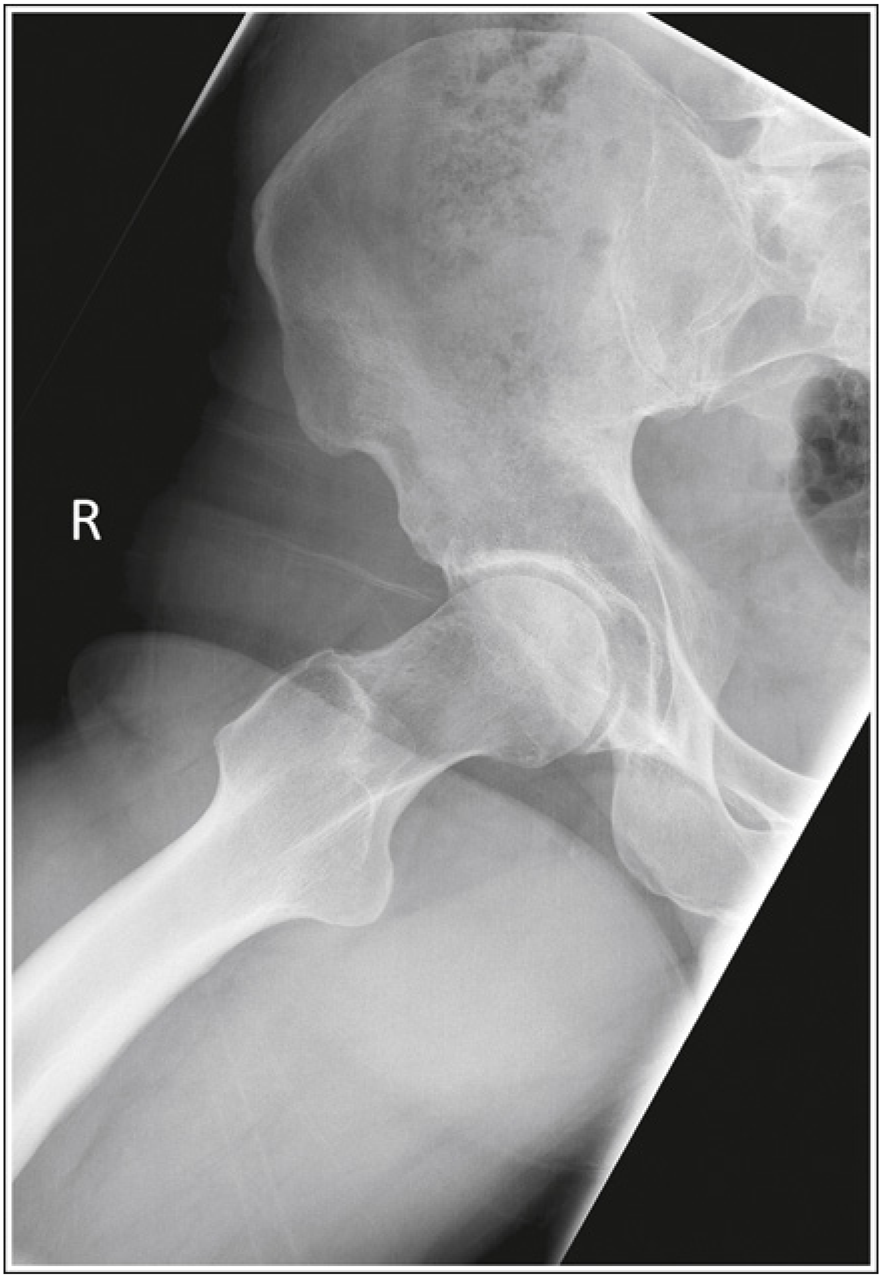


IMAGE 7.9

Analysis

The ischial spine is demonstrated without pelvic brim superimposition, the sacrum and coccyx are not aligned with the pubis symphysis but are rotated away from the affected hip, and the obturator foramen demonstrates

decreased foreshortening. The pelvis was rotated toward the right hip. The femoral neck is demonstrated without foreshortening and the greater and lesser trochanters are at about the same transverse level. The femurs were abducted less than 45 degrees with the IR.

Correction

Rotate the pelvis away from the affected hip until the ASISs are positioned at equal distances from the IR and increase the degree of femoral abduction until the femur is positioned at a 45-degree angle with the IR.

IMAGE 7.10

Analysis

The ischial spine is not aligned with the pelvic brim but is demonstrated closer to the acetabulum, the sacrum and coccyx are not aligned with the pubis symphysis but are rotated toward the affected hip, and the obturator foramen demonstrates decreased foreshortening. The pelvis was rotated away from the affected hip. A small amount of the posterior aspect of the greater trochanter is seen medially and is partially obscuring the lesser trochanter. The knee and hip were flexed more than 60 to 70 degrees with the IR. The femoral neck is demonstrated on end and is entirely foreshortened and the proximal greater trochanter is demonstrated on the same transverse level as the femoral head. The femur was abducted until it was positioned close to or flat against the table.

Correction

Rotate the pelvis toward the affected hip until the ASISs are positioned at equal distances from the IR, extend the leg until the femur is at a 60- to 70-degree angle with the IR, and adduct the femur until it is at a 45-degree angle with the IR.

Hip: Axiolateral (Inferosuperior) Projection (Danelius-Miller Method)

See **Table 7.10** and **Figs. 7.62** and **7.63**.

TABLE 7.10

CR, Central ray; *IR*, image receptor.

Pelvis Tilt or Insufficient Leg Flexion

Maximum leg flexion of the unaffected leg may cause the midsagittal plane to tilt with the longitudinal axis of the imaging table so the unaffected side's pelvis is closer to the head of the table than the affected side's pelvis by 15 to 20 degrees or 2 to 3 inches (5 to 7.6 cm). This tilt brings the affected side's acetabulum in profile and moves the superior ramus medial to the femoral head and neck so it does not superimpose them on the resulting projection (**Fig. 7.64**).

When the projection is obtained with inadequate flexion or abduction of the unaffected leg and/or if the pelvis is not tilted, the resulting projection will not demonstrate the affected acetabulum in profile and will demonstrate the unaffected leg's soft tissue and the superior ramus superimposed over the femoral head and neck (**Fig. 7.65**). The large underexposed area caused by the unaffected leg's soft tissue may also cause a histogram analysis error. If the patient is unable to flex or abduct the unaffected leg the needed amount, tilt the pelvis so the unaffected side's pelvis is 2 to 3 inches (5 to 7.6 cm) superior to the affected side to improve this projection.

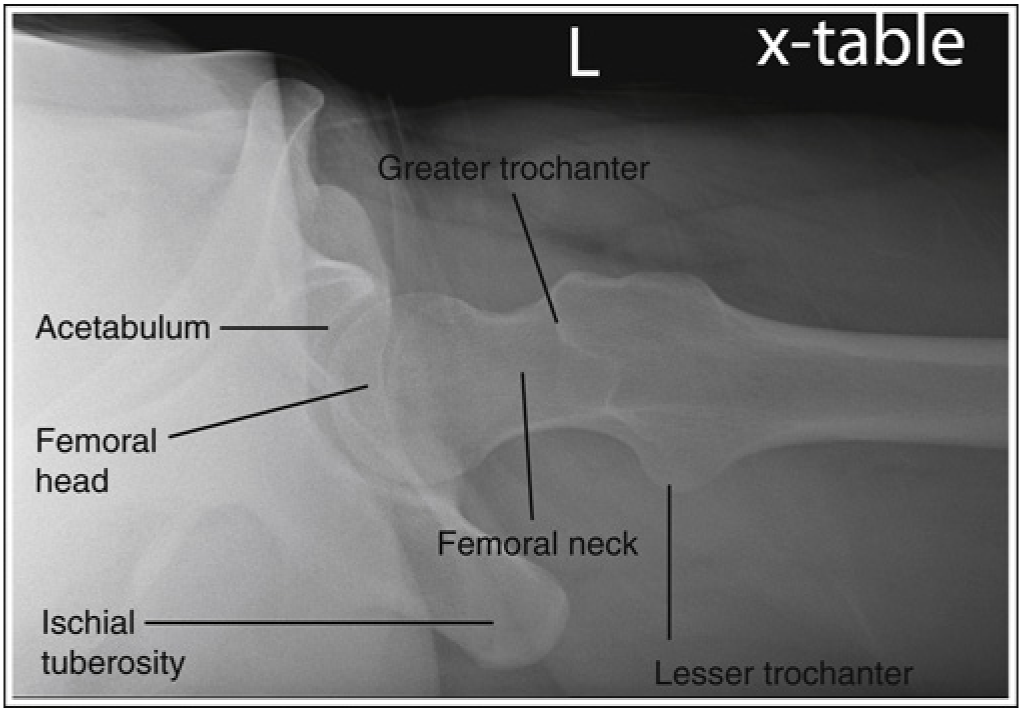


FIGURE 7.62 Axiolateral hip projection with accurate positioning.

Excessive Femur to CR Angle

If the angle formed between the femur and the CR is more than 45 degrees, the femoral neck has been foreshortened and the proximal greater trochanter is demonstrated proximal to the transverse level of the lesser trochanter and is superimposed by a portion of the femoral neck (**Fig. 7.66**).

Insufficient Femur to CR Angle

If the angle between the femur and the CR is less than 45 degrees, the femoral neck is foreshortened and the proximal greater trochanter would be demonstrated closer to or distal to the transverse level of the lesser trochanter. This mispositioning does not occur because the imaging table and x-ray tube alignment possibilities make such an angle unobtainable.

External Leg Rotation

If the affected leg is not rotated internally for the axiolateral hip projection, the greater trochanter is demonstrated posteriorly and the lesser trochanter is obscured (**Fig. 7.67**). How much of the greater trochanter is demonstrated without femoral shaft superimposition depends on the degree of external rotation. Greater external rotation increases the amount of the greater trochanter than is shown.

Proximal Femur or Femoral Neck Fracture

When an axiolateral hip projection is requested and the patient has a suspected proximal femur or femoral neck fracture, the leg should not be internally rotated but left as it is unless indicated by your facility. Because the leg is not internally rotated in such cases, it is acceptable for the greater trochanter to be demonstrated posteriorly and the lesser trochanter to be superimposed over the femoral shaft (**Fig. 7.68**).

FIGURE 7.63 Proper patient positioning for axiolateral hip projection.

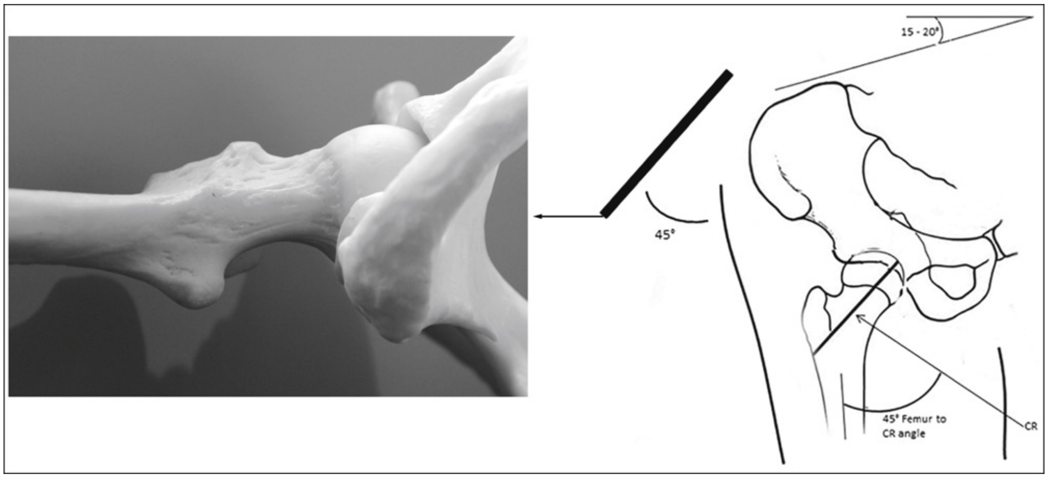


FIGURE 7.64 Accurate pelvis tilt, femur-to-CR angle, and IR placement for an axiolateral right hip projection.

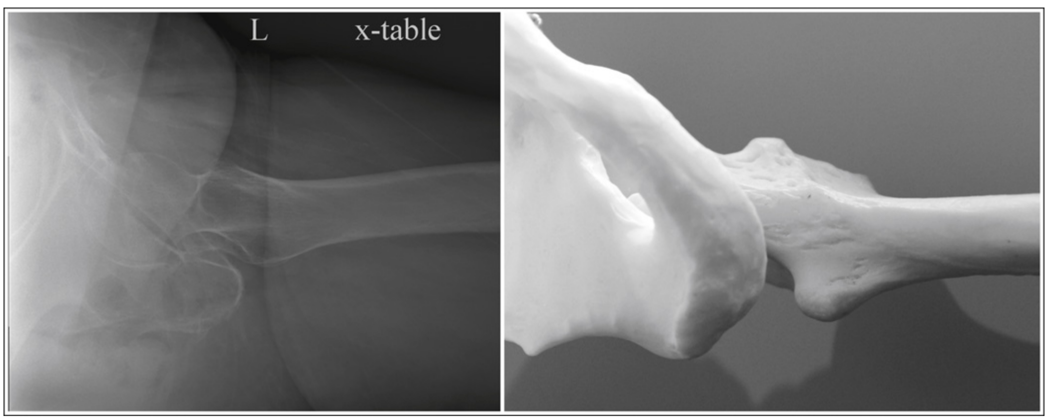


FIGURE 7.65 Axiolateral hip projection obtained without pelvis tilt. Superior ramus of pelvis is superimposing the femoral head and neck.

Hip Dislocation

When an axiolateral hip projection is requested and a hip dislocation is suspected, the affected leg should not be internally rotated but left as it is.

The resulting projection will demonstrate the femoral head proximal and anterior to the acetabulum (**Fig. 7.69**).

Hip and Proximal Femur Orthopedic Apparatuses

When an axiolateral hip projection is requested and the patient has had an orthopedic apparatus placed in the hip joint or proximal femur, the entire apparatus is to be included on the resulting projection (**Fig. 7.70**). This may require the use of a larger IR and more distal placement of the IR and CR centering.

Obese Patient

For patients with ample lateral soft tissue thickness, the upper edge of the IR and grid needs to be positioned superior to the iliac crest (**Fig. 7.71**). This superior positioning will result in magnification because of the increase in the object–IR distance (OID) but is necessary if the acetabulum and femoral head are to be included on the axiolateral hip projection.

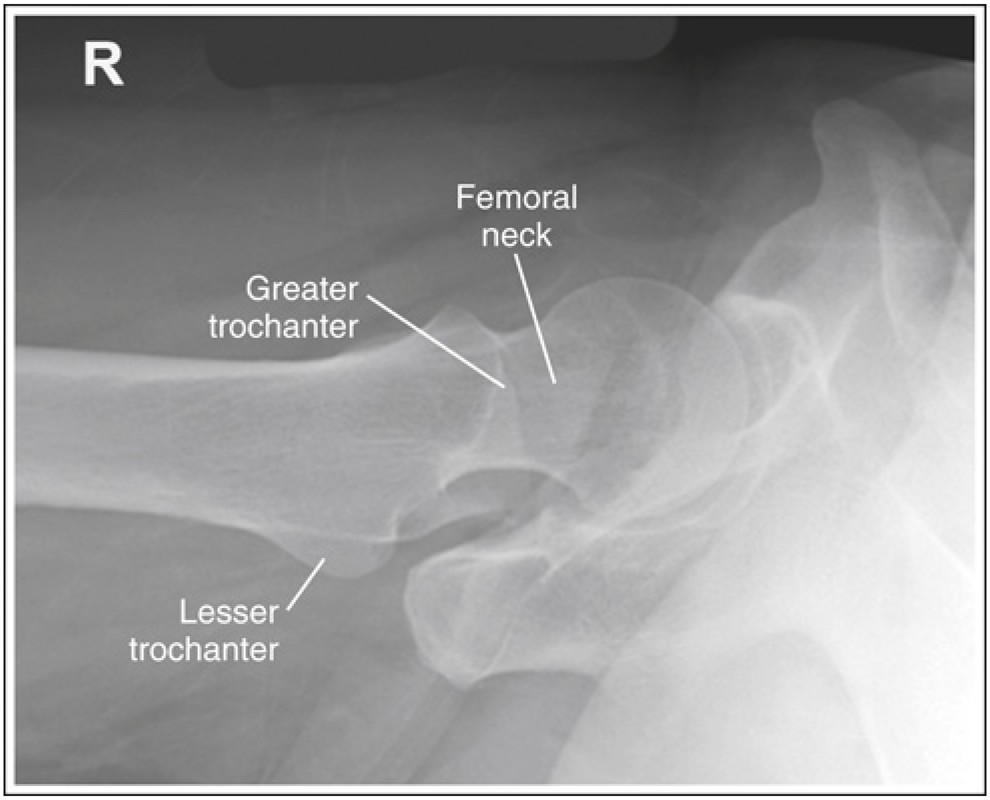


FIGURE 7.66 Axiolateral hip projection taken with too large of a femur to CR angulation.

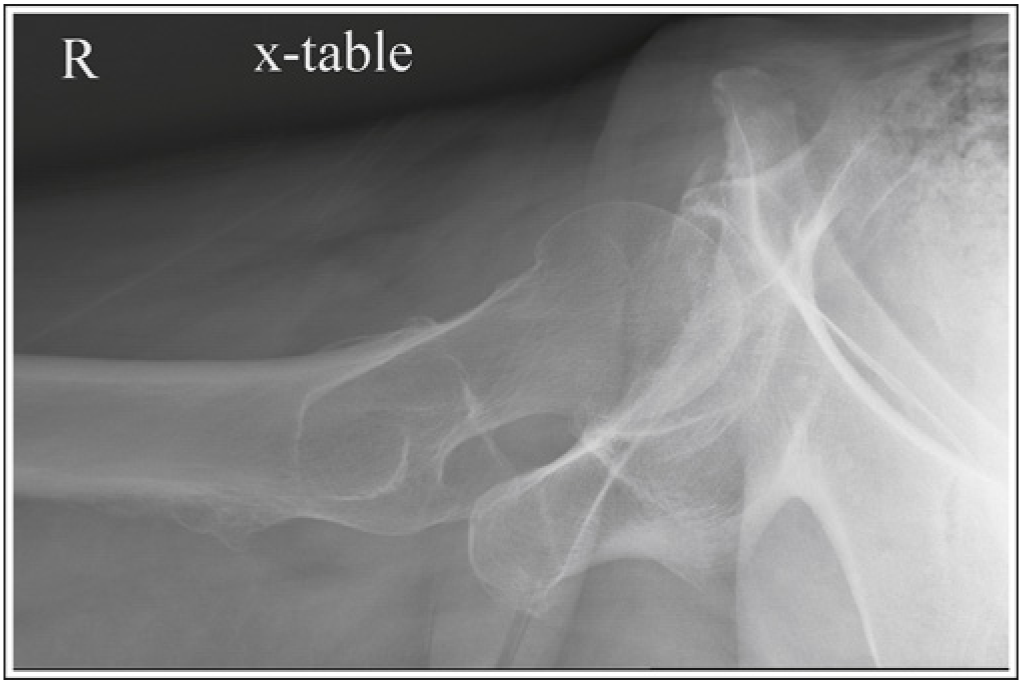


FIGURE 7.67 Axiolateral hip projection taken with the leg externally rotated.

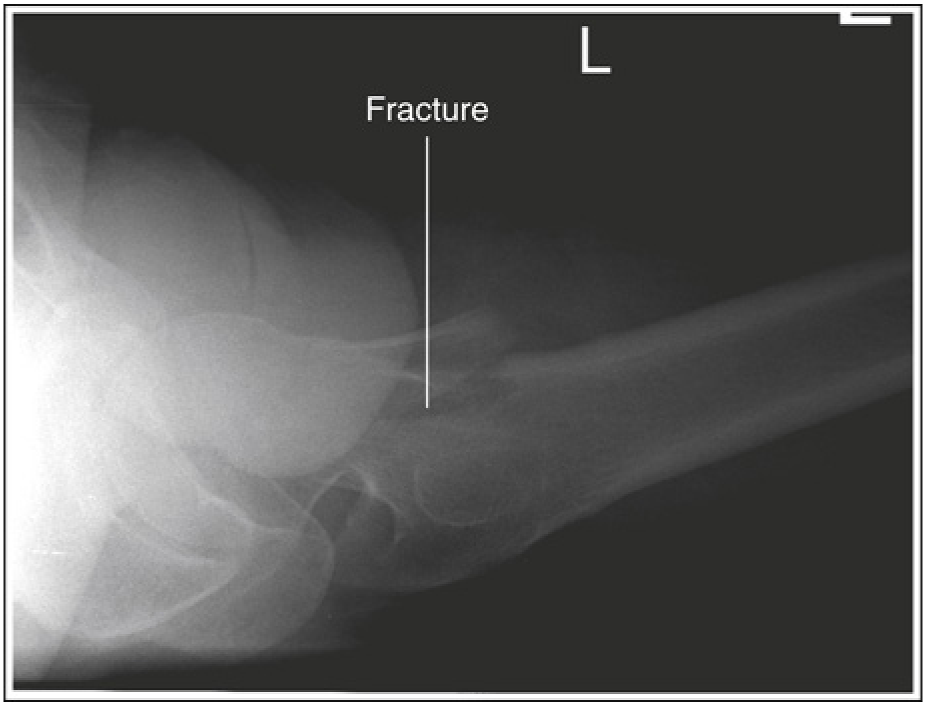


FIGURE 7.68 Axiolateral hip projection demonstrating a fractured femoral neck.

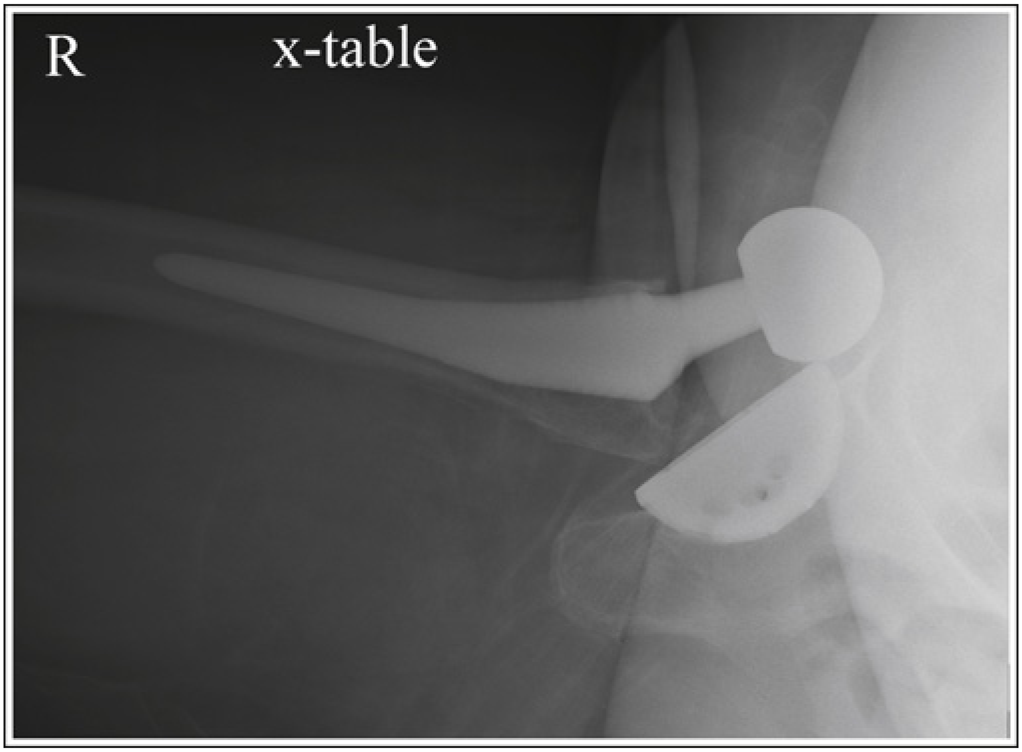


FIGURE 7.69 Axiolateral hip projection demonstrating a hip dislocation on patient with a total hip replacement.

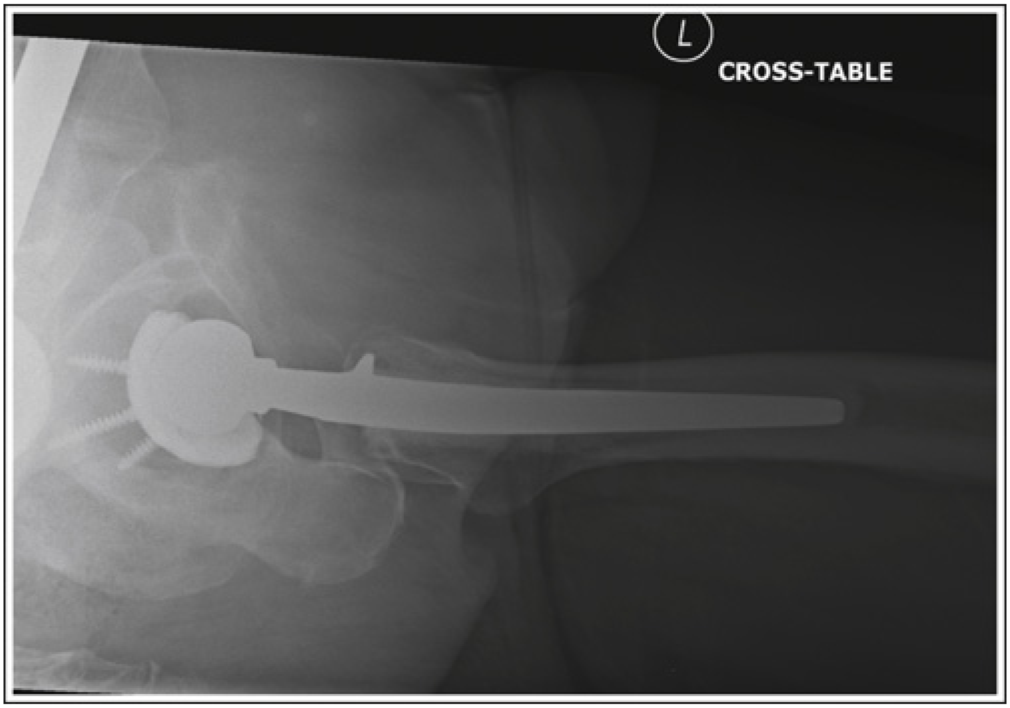


FIGURE 7.70 Axiolateral hip projection of patient with a metal apparatus.

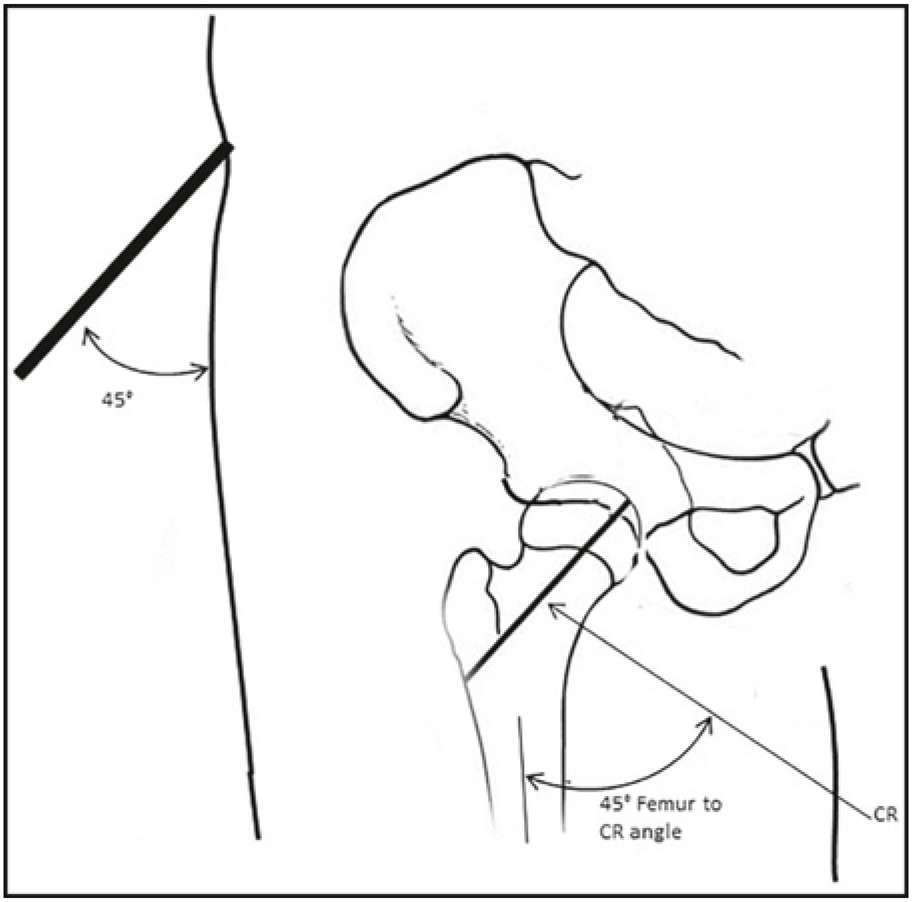


FIGURE 7.71 Proper IR placement for obese patients.

Axiolateral Hip Analysis Practice

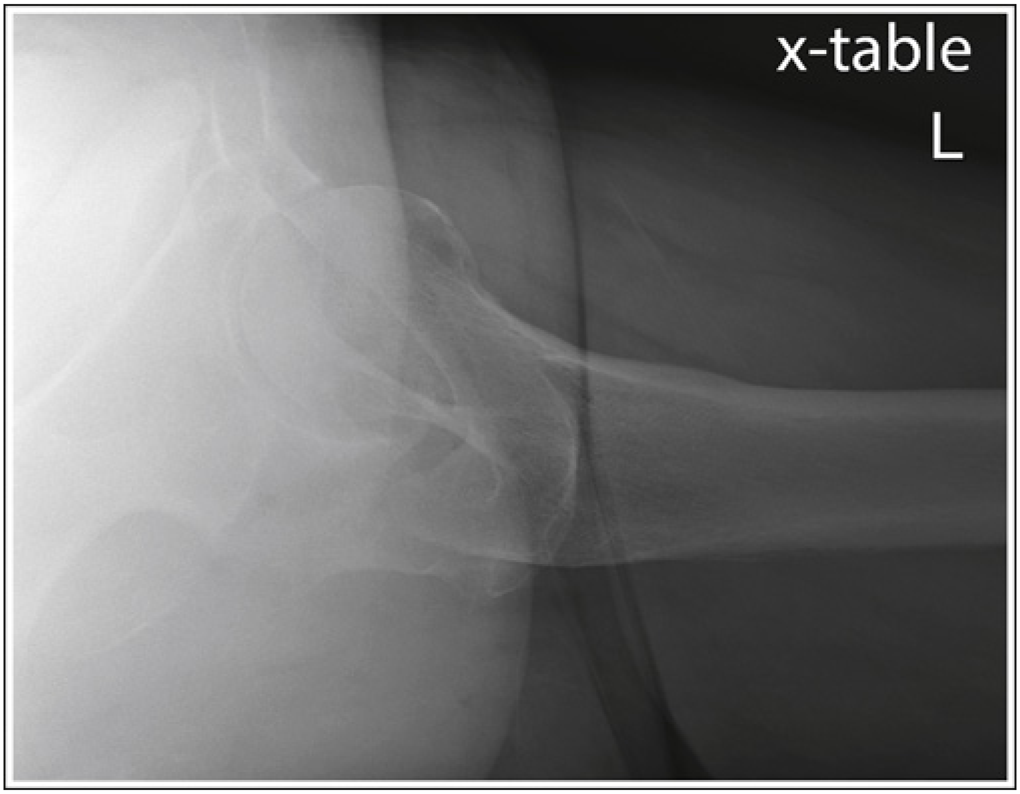


IMAGE 7.11

Analysis

Soft tissue from the unaffected thigh and the superior ramus of the pelvis are superimposing the femoral head and neck of the affected hip. The unaffected leg was not adequately flexed and abducted, causing the sides of the pelvis to stay on the same transverse plane. The greater trochanter is demonstrated posteriorly and the lesser trochanter is superimposed over the femoral shaft. The affected leg was in external rotation.

Correction

Flex and abduct the unaffected leg as much as the patient can tolerate. If the patient is unable to increase flexion and abduction of the unaffected leg, tilt the pelvis so the unaffected side is 2 to 3 inches (5 to 7.6 cm) higher than

the affected side of the pelvis, and internally rotate the leg until the femoral epicondyles are aligned parallel with the IR and the foot is angled internally 15 to 20 degrees from vertical.

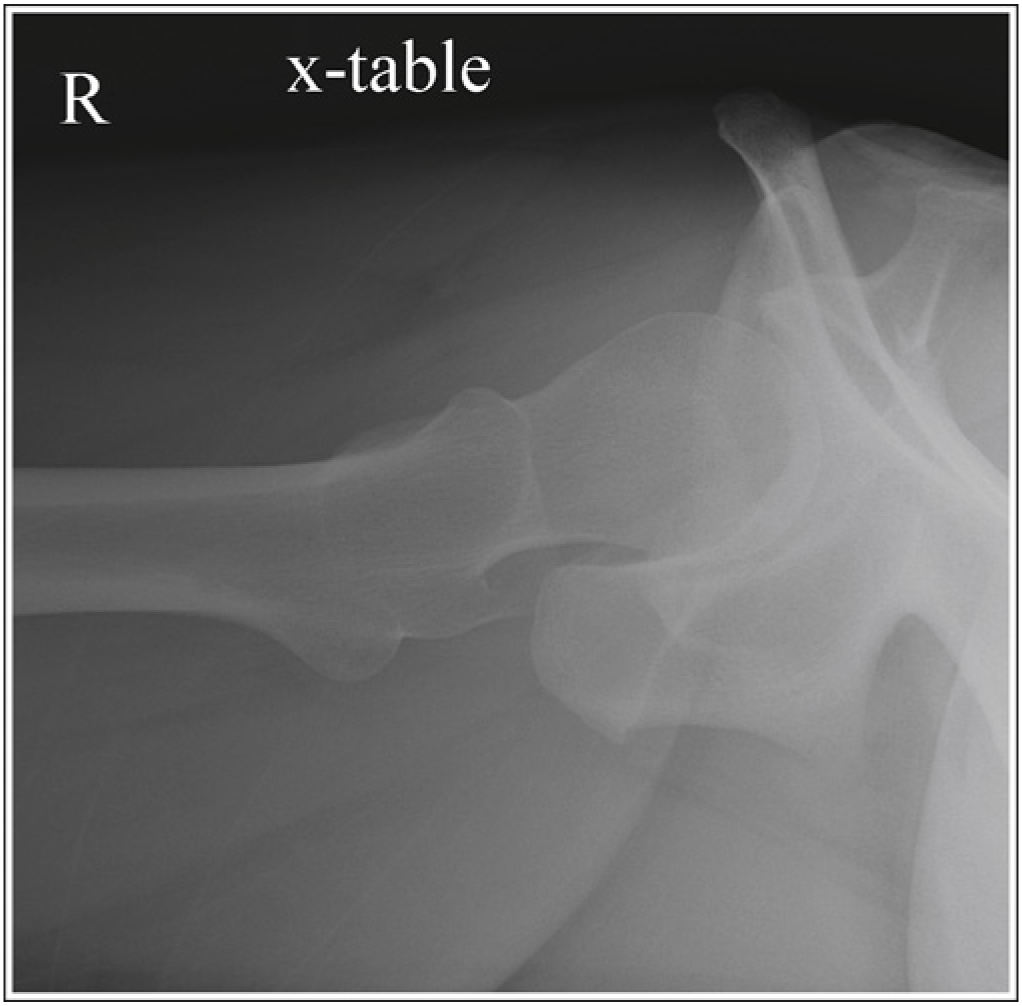


IMAGE 7.12

Analysis

The greater trochanter is demonstrated at a transverse level halfway between the lesser trochanter and femoral head. The femur to CR angle was too large.

Correction

Reduce the femur to CR angle until it is 45 degrees.

Sacroiliac (SI) Joints: AP Axial Projection

See **Table 7.11** and **Figs. 7.72** and **7.73**.

Pelvis Rotation

If the pelvis is rotated into an LPO position, the median sacral crest is rotated toward the right pelvic brim (**Fig. 7.74**). If the pelvis is rotated into an RPO position, the median sacral crest is rotated toward the left pelvic brim.

CR Angulation

When the patient is placed in a supine AP projection, with the legs extended, the lumbosacral curve causes the proximal sacrum and SI joints to be angled 30 to 35 degrees with the IR. To demonstrate the SI joints without foreshortening, a 30-degree cephalic angle is used for male patients and a 35-degree cephalic angle is used for female patients. Patients with less than the average lumbosacral curvature or who cannot fully extend their legs will require a decrease in cephalic CR angulation to maintain the 30- to 35-degree alignment of the CR and SI joints, and patients with a greater than average lumbosacral curve will require an increase in cephalic CR angulation.

Insufficient Cephalic CR Angulation

If an AP axial SI joint projection is taken with a perpendicular CR or without enough cephalad angulation, the SI joints and the first through third

sacral segments are foreshortened and the pubis symphysis is demonstrated inferior to the fifth sacral segment (**Fig. 7.75**).

Excessive Cephalic CR Angulation

If the AP axial SI joint projection is taken with too much cephalic angulation, the sacrum and SI joints demonstrate excessive elongation and the pubis symphysis is superimposed over more than only the fifth of the sacral segment (**Fig. 7.76**).

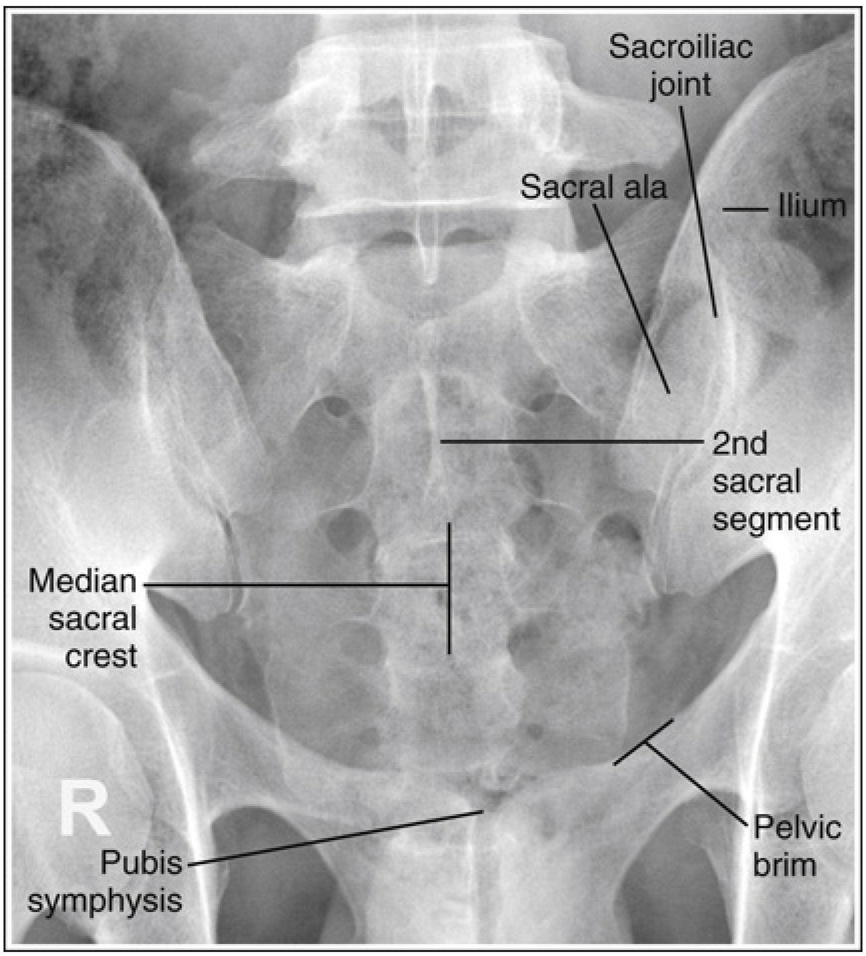


FIGURE 7.72 AP axial SI joint projection with accurate positioning.

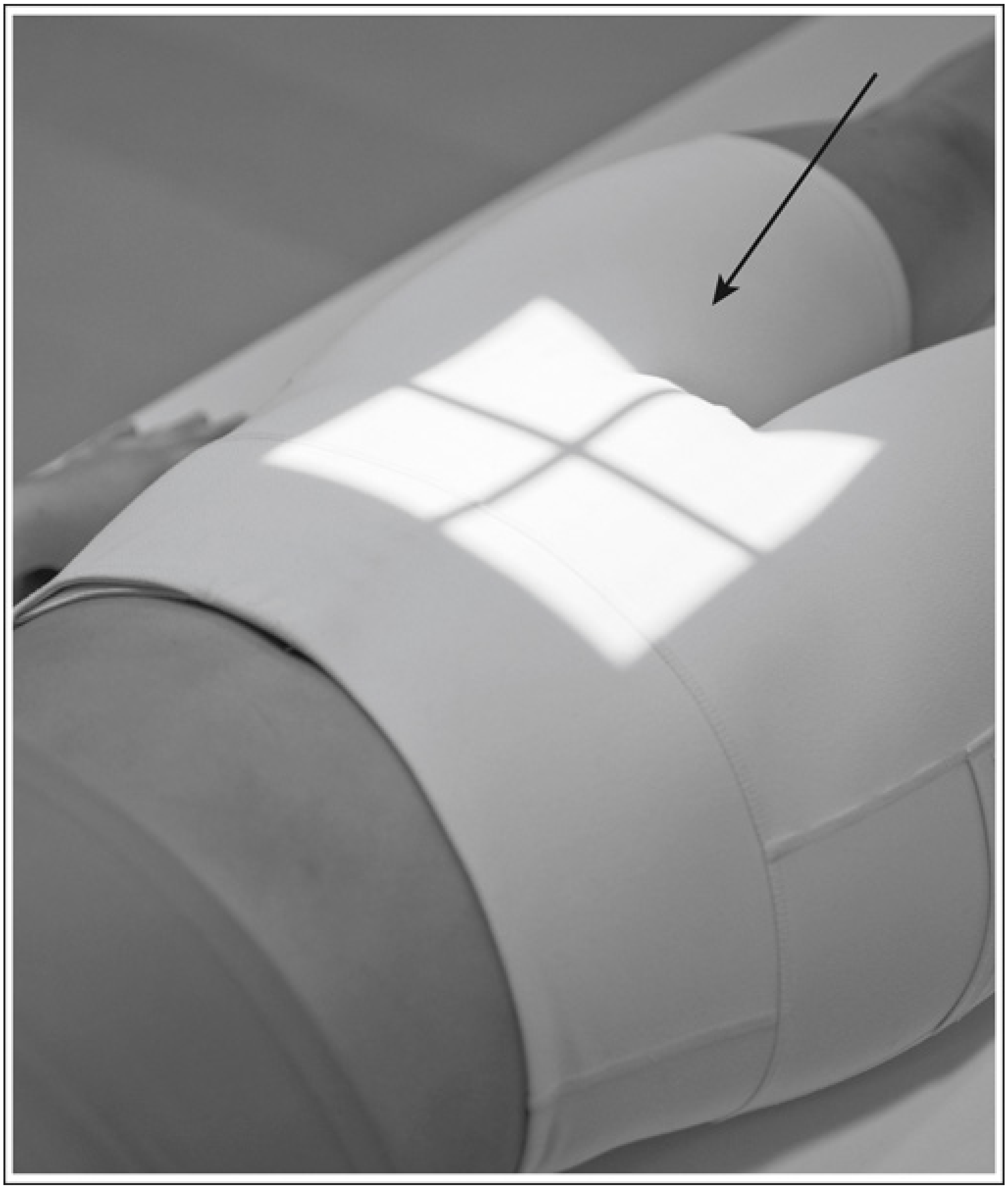


FIGURE 7.73 Proper patient positioning for AP axial SI joint projection.

FIGURE 7.74 AP axial SI joints projection taken with the left side of pelvis rotated closer to IR (LPO position).

FIGURE 7.75 AP axial SI joints projection taken with insufficient cephalic angulation.

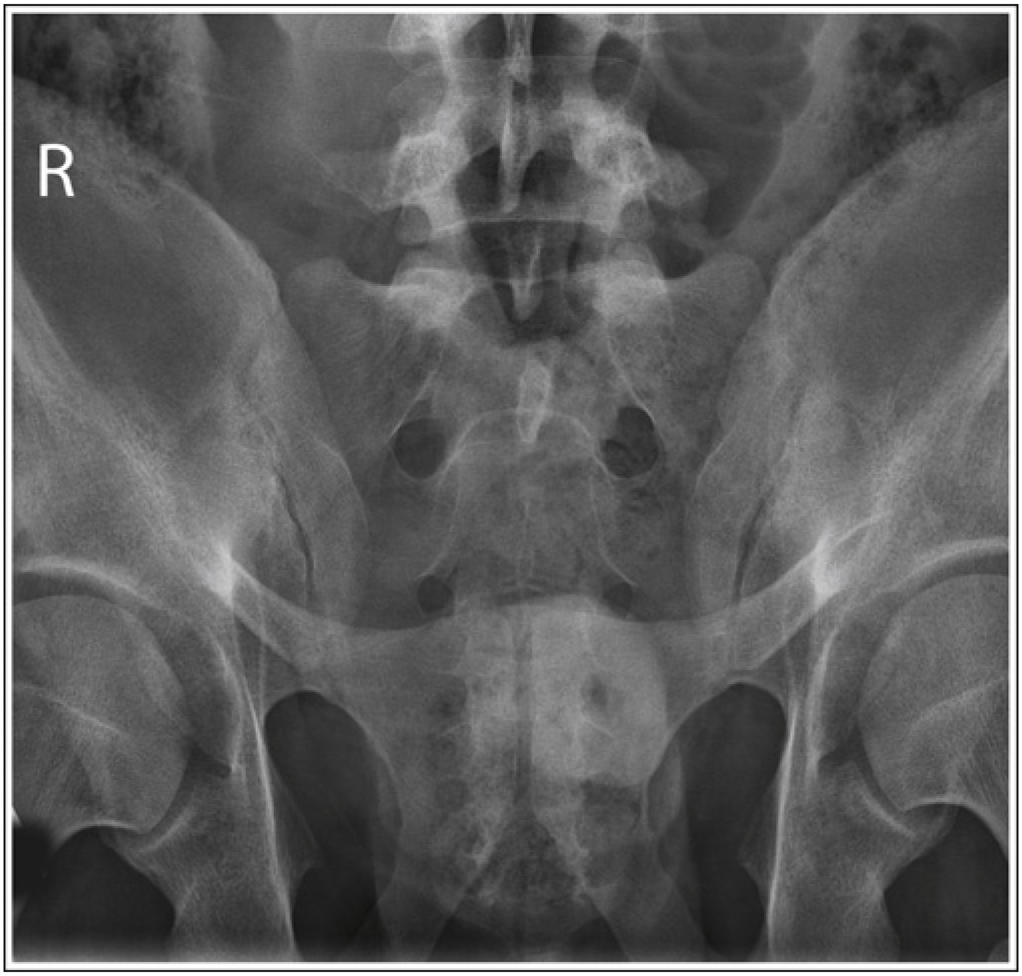


FIGURE 7.76 AP axial SI joints projection taken with excessive cephalic angulation.

TABLE 7.11

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor; *SI*, sacroiliac.

AP Axial SI Joint Analysis Practice

IMAGE 7.13

Analysis

The SI joints are foreshortened, and the pubis symphysis is inferior to the fifth sacral segment. The CR was insufficiently angled.

Correction

Increase the degree of cephalic CR angulation.

IMAGE 7.14

Analysis

The SI joints are elongated, and the pubis symphysis is superimposed over the fourth and fifth sacral segments. The CR was excessively angled.

Correction

Decrease the degree of cephalic CR angulation.

SI Joints: AP Oblique Projection (LPO and RPO Positions)

See **Table 7.12** and **Figs. 7.77** and **7.78**.

SI Joint Openness: Insufficient Pelvis Obliquity

The degree of separation or cavity demonstrated between the ilium and sacrum, which represents the SI joint, varies from patient to patient. The ilia and sacrum fit very snugly together and in older patients the joint spaces between them may be smaller or even nonexistent because of fibrous adhesions or synostosis. If the pelvis was rotated less than 25 to 30 degrees with the IR, the resulting AP oblique SI joint projection will demonstrate a closed SI joint, the iliac tuberosity demonstrated medial to the lateral ala, the ilium demonstrating decreased lateromedial foreshortening, and the lateral sacrum seen without ilium superimposition (**Fig. 7.79**).

SI Joint Openness: Excessive Pelvis Obliquity

If the pelvis was rotated more than 25 to 30 degrees with the IR, the resulting AP oblique SI joint projection will demonstrate a closed SI joint, the ilium with increased lateromedial foreshortening, and the ilium superimposed over the lateral sacral ala and lateral sacrum (**Fig. 7.80**).

TABLE 7.12

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor; *SI*, sacroiliac.

FIGURE 7.77 AP oblique SI joint projection with accurate positioning.

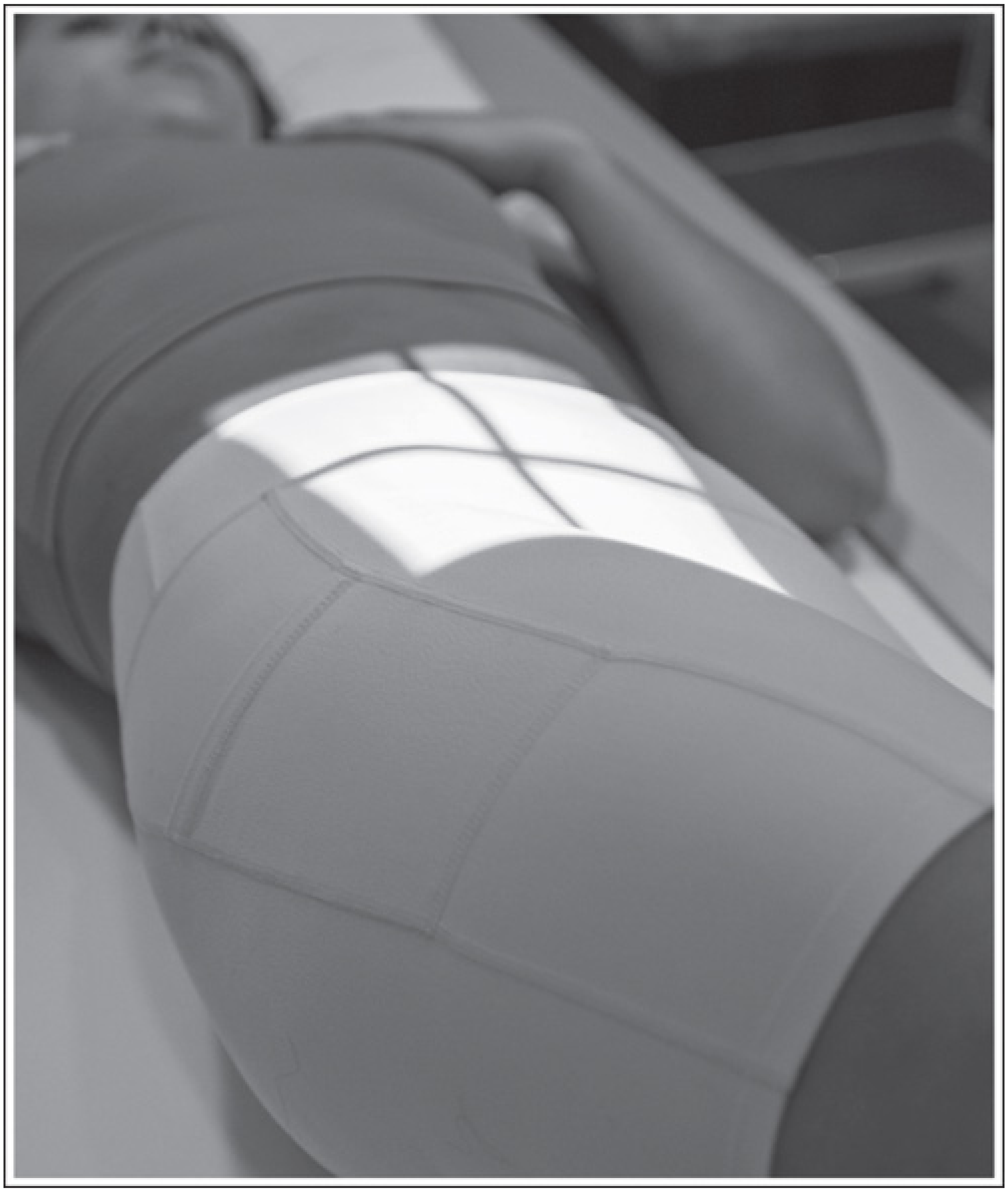


FIGURE 7.78 Proper patient positioning for AP oblique SI joint projection.

FIGURE 7.79 AP oblique SI joint taken with insufficient pelvic obliquity.

FIGURE 7.80 AP oblique SI joint taken with excessive pelvic obliquity.

AP Oblique SI Joint Analysis Practice

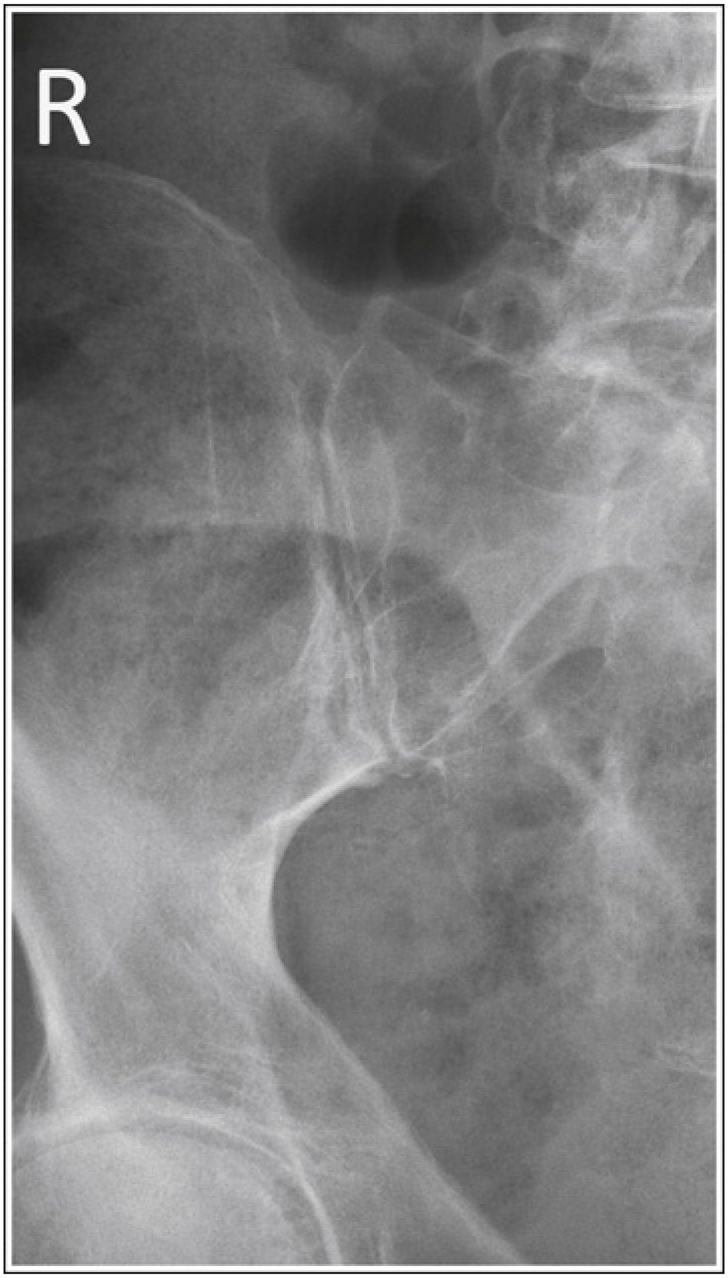


IMAGE 7.15

Analysis

The SI joint is closed, the iliac tuberosity is medial to the lateral ala, the ilium demonstrates decreased lateromedial foreshortening, and the lateral sacrum is not superimposed by the ilium. The pelvis was underrotated.

Correction

Increase the pelvic obliquity.

IMAGE 7.16

Analysis

The SI joint is closed, the ilium demonstrates increased lateromedial foreshortening, and the ilium superimposes over the lateral sacral ala and lateral sacrum. The pelvis was overrotated.

Correction

Decrease pelvic rotation.

Chapter 8: Image Analysis of the Cervical and Thoracic Vertebrae

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Identify the required anatomy on cervical and thoracic vertebral projections.
- Describe how to position the patient, image receptor (IR), and central ray (CR) properly for cervical and thoracic vertebral projections.
- List the image analysis guidelines for cervical and thoracic vertebral projections with accurate positioning.
- State how to reposition the patient properly when cervical and thoracic vertebral projections with poor positioning are produced.
- Discuss how to determine the amount of patient or CR adjustment required to improve cervical and thoracic vertebral projections with poor positioning.
- State the technical factors routinely used for cervical and thoracic vertebral projections, and describe which anatomic structures are demonstrated when the correct technique factors are used.
- Describe how the upper and lower cervical vertebrae can move simultaneously and independently.
- Explain how a patient with a suspected subluxation or fracture of the cervical vertebral column is positioned for cervical projections.
- Discuss the curvature of the cervical vertebrae, and explain how the intervertebral disk spaces slant.
- Describe why a 5-degree cephalic CR angulation is often required for an AP open-mouth projection of the atlas and axis.

- State how the relationship between the dens and atlas's lateral masses changes when the head is rotated.
- Describe how the prevertebral fat stripe is used as a diagnostic tool.
- Explain how the patient is positioned to demonstrate anteroposterior (AP) cervical mobility.
- Discuss the procedures that are taken if C7 is not demonstrated on a lateral cervical projection.
- Describe the positioning and analysis differences that exist between AP and posteroanterior (PA) oblique cervical projections.
- Discuss when it is necessary to achieve a lateral cervicothoracic projection of the cervical vertebrae.
- Describe the curvature of the thoracic vertebrae.
- List two methods used to obtain uniform image density on an AP thoracic vertebral projection.
- Discuss how scoliosis is differentiated from rotation on AP and lateral thoracic projections.
- Explain the breathing methods used to demonstrate the thoracic vertebrae on a lateral thoracic projection.
- Describe two methods that are used to offset the sagging of the lower thoracic column that results when the patient is in a lateral projection.

KEY TERMS

acanthiomeatal line

breathing technique

costal breathing

external auditory meatus

infraorbitomeatal line

interpupillary line

prevertebral fat stripe

Image Analysis Guidelines

Technical Data

See **Table 8.1** and **Box 8.1**.

Cervical Vertebrae: AP Axial Projection

See **Table 8.2** and **Figs. 8.1** and **8.2**.

Cervical Rotation

When the patient and cervical vertebrae are rotated away from the anteroposterior (AP) axial projection, the vertebral bodies move toward the side positioned closer to the image receptor (IR), and the spinous processes move toward the side positioned farther from the IR. The upper (C1-C4) and lower (C5-C7) cervical vertebrae can demonstrate rotation independently or simultaneously, depending on which part of the body is rotated. If the head is rotated but the thorax remains in an AP projection, the upper cervical vertebrae demonstrate rotation as C1 rotates on C2 and the lower cervical vertebrae remain in an AP projection. If the thorax is rotated but the head remains in a forward position, the lower cervical vertebrae demonstrate rotation and the upper cervical vertebrae remain in an AP projection (**Fig. 8.3**). If the head and thorax are rotated simultaneously, the entire cervical column demonstrates rotation.

TABLE 8.1

AEC, Automatic exposure control; *AP*, anteroposterior; *PA*, posteroanterior; *SID*, source–image receptor distance.

* Optional because of air gap.

Box 8.1 Cervical and Thoracic Vertebrae Guidelines

VOI, Values of interest.

- The facility's identification requirements are visible.
- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomic structures are sharply defined.
- Contrast resolution is adequate to demonstrate the surrounding soft tissue, air-filled trachea, bony trabecular patterns, and cortical outlines.
- No quantum mottle or saturation is present.
- Scatter radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

Rotation is present on an AP axial projection in the following situations: (1) if the mandibular angles and mastoid tips are not demonstrated at equal distances from the cervical vertebrae; (2) if the spinous processes are not demonstrated in the midline of the cervical bodies; (3) if the pedicles and articular pillars are not symmetrically demonstrated lateral to the vertebral

bodies; and (4) if the medial ends of the clavicles are not demonstrated at equal distances from the vertebral column. The side of the patient positioned closer to the IR and toward which the mandible is rotated is the side that the vertebral bodies are rotated toward and demonstrates fewer articular pillars and less clavicular and vertebral column superimposition.

CR Alignment: Intervertebral Disk Space Openness

The cervical vertebral column demonstrates a lordotic curvature. This curvature and the shape of the vertebral bodies cause the disk-articulating surfaces of the vertebral bodies to slant upward anteriorly to posteriorly. To obtain open intervertebral disk spaces and undistorted vertebral bodies, the central ray (CR) must be angled in the same direction as the slope of the vertebral bodies. This can be easily discerned by viewing the lateral cervical projection in **Fig. 8.4**. Studying this lateral cervical projection, you can see that when the correct CR angulation is used, each vertebra's spinous process is located within its inferior intervertebral disk space. The degree of CR angulation needed to obtain open intervertebral disk spaces and to align the spinous processes within them accurately depends on the degree of cervical lordotic curvature.

TABLE 8.2

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor.

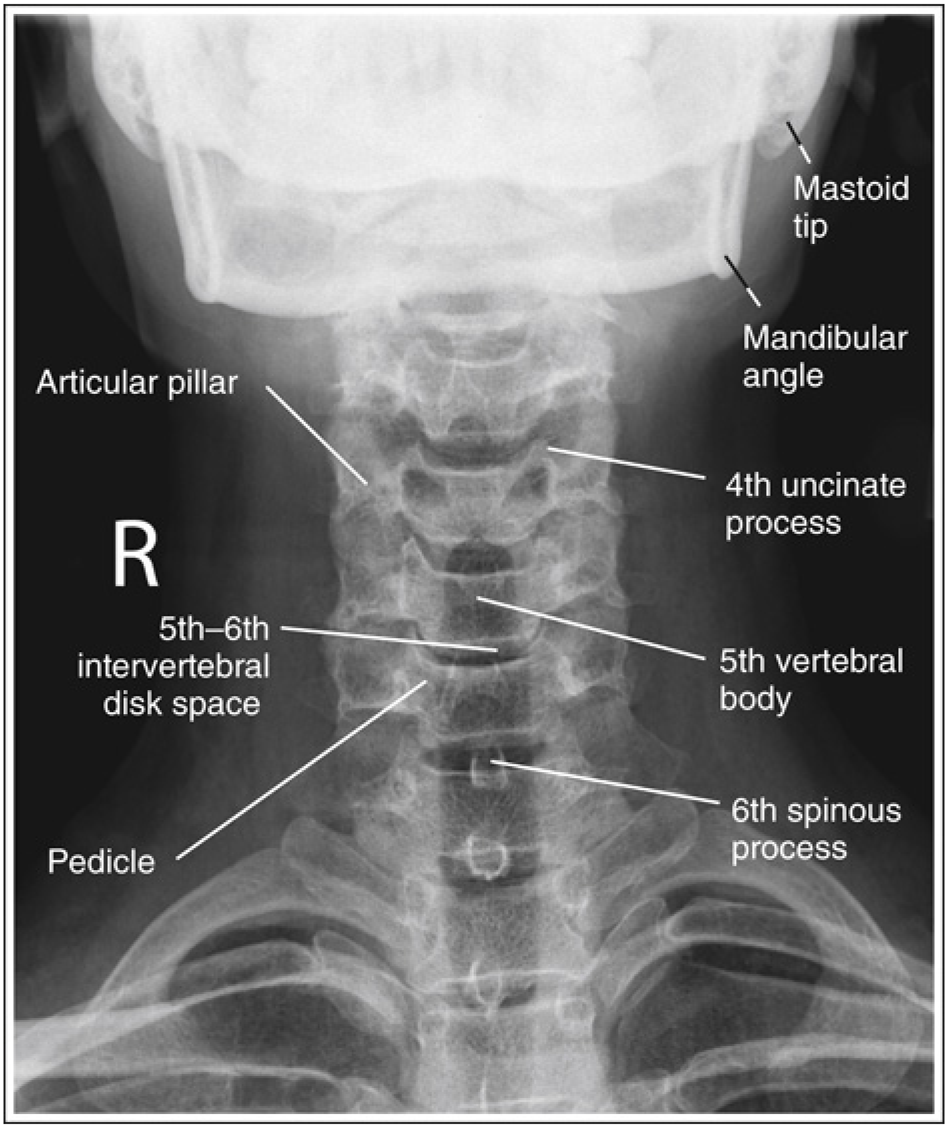


FIGURE 8.1 AP axial cervical vertebrae projection with accurate positioning.

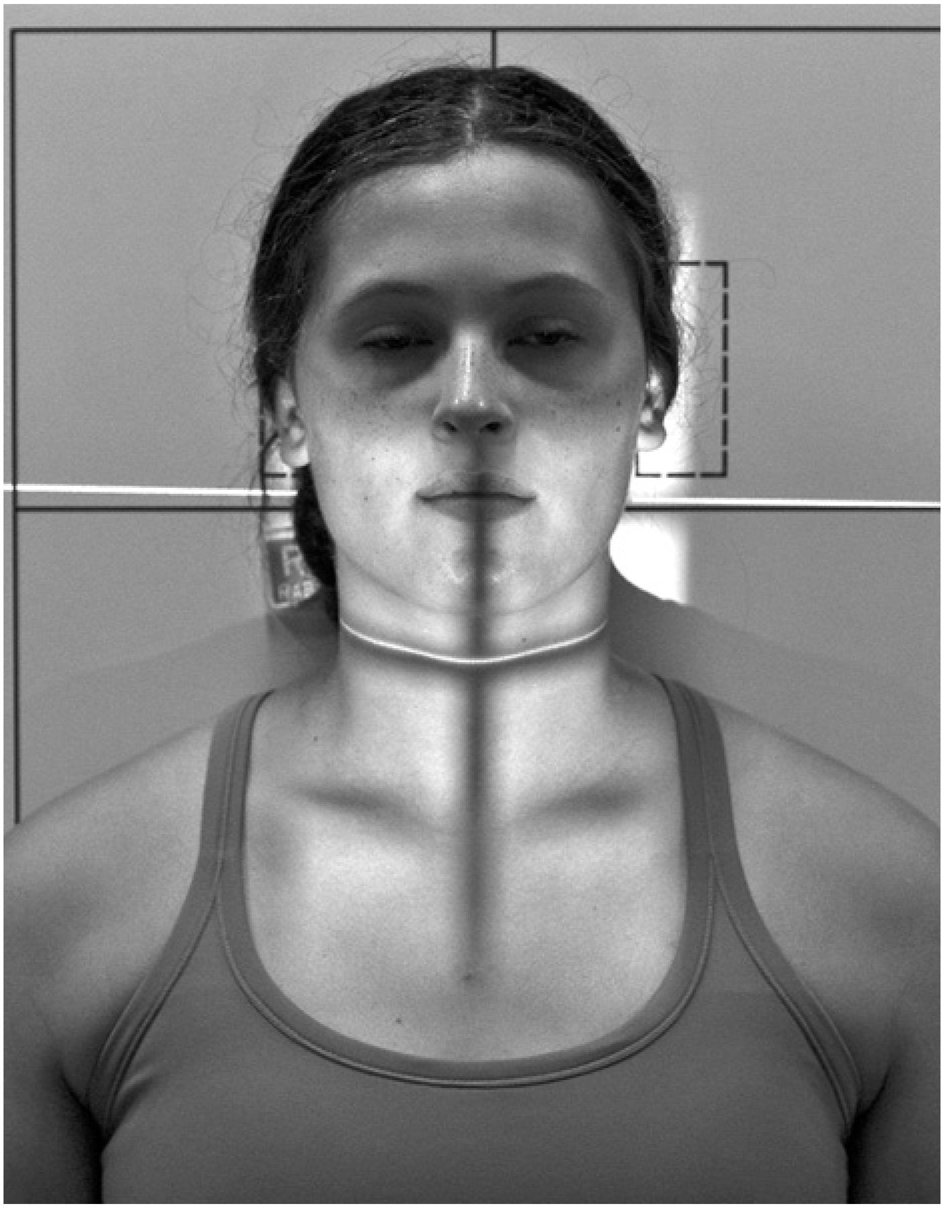


FIGURE 8.2 Proper patient positioning for AP axial cervical vertebrae projection.

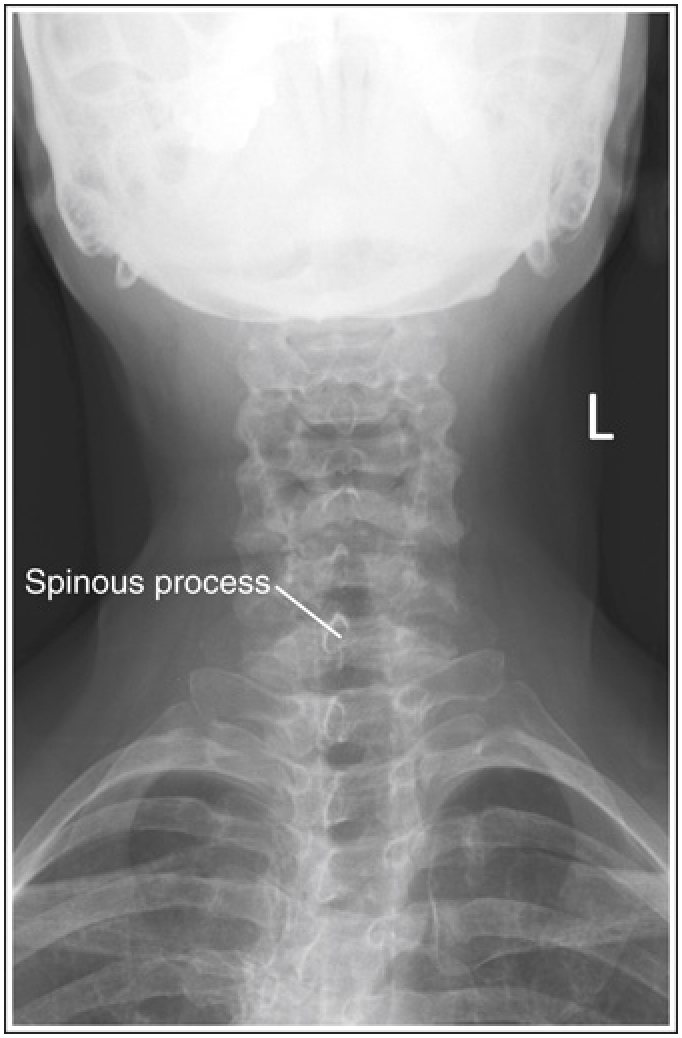


FIGURE 8.3 AP axial cervical projection taken with thorax rotated toward the left side.

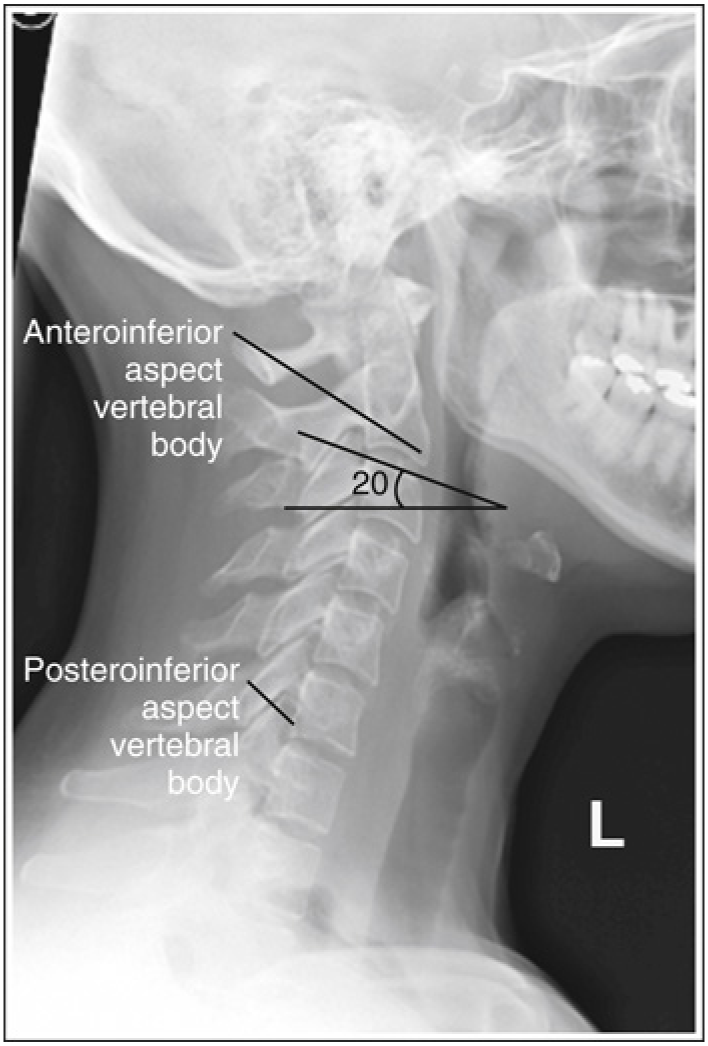


FIGURE 8.4 Lateral cervical vertebrae projection taken with patient upright.

Upright Versus Supine Position

If the AP axial projection is performed with the patient in an upright position, the cervical vertebrae demonstrate more lordotic curvature than if the examination is performed with the patient supine. In a supine position, the gravitational pull placed on the middle cervical vertebrae results in straightening of the cervical curvature. **Fig. 8.4** demonstrates a lateral cervical projection taken with the patient in an upright position, and **Fig. 8.5**

demonstrates a lateral cervical projection taken with the patient supine. Note the difference in lordotic curvature between these two projections. Because of this difference, the CR angulation is varied when an AP axial projection is taken with the patient erect rather than supine. In the erect position, a 20-degree cephalad CR angulation is needed to align the CR parallel with the intervertebral disk spaces, and in the supine position, a 15-degree cephalad CR angulation sufficiently aligns the CR parallel with the intervertebral disk spaces.

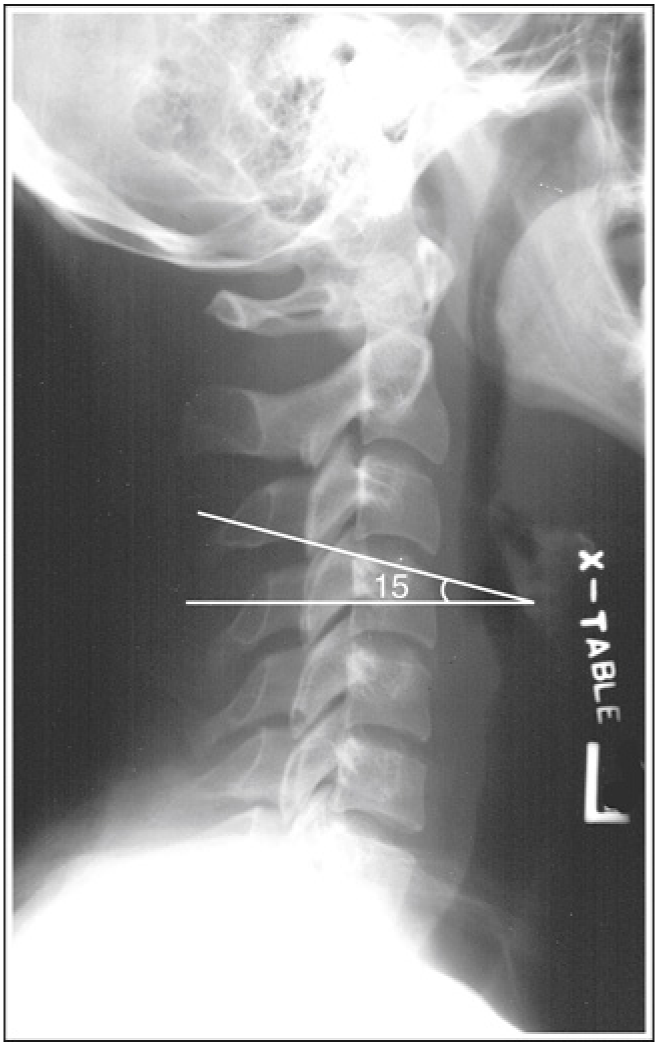


FIGURE 8.5 Lateral cervical vertebrae projection taken with patient supine.

Kyphotic Patient

The kyphotic patient demonstrates an exaggerated kyphotic curvature of the thoracic vertebrae that will cause excessive lordotic curvature of the cervical vertebrae. To demonstrate the cervical vertebrae with open intervertebral spaces for an upright AP axial projection, it will be necessary to adjust the degree of CR angulation above that routinely needed for a patient without kyphosis, depending on the severity of the condition. **Fig.**

8.6 demonstrates a kyphotic patient requiring a 30-degree CR angulation to demonstrate open intervertebral disk spaces. If the AP axial projection is taken with the kyphotic patient in a supine position, a radiolucent sponge should be placed beneath the head to prevent the upper cervical vertebrae from extending toward the imaging table and from superimposing the occipital base on the projection (Fig. 8.7).

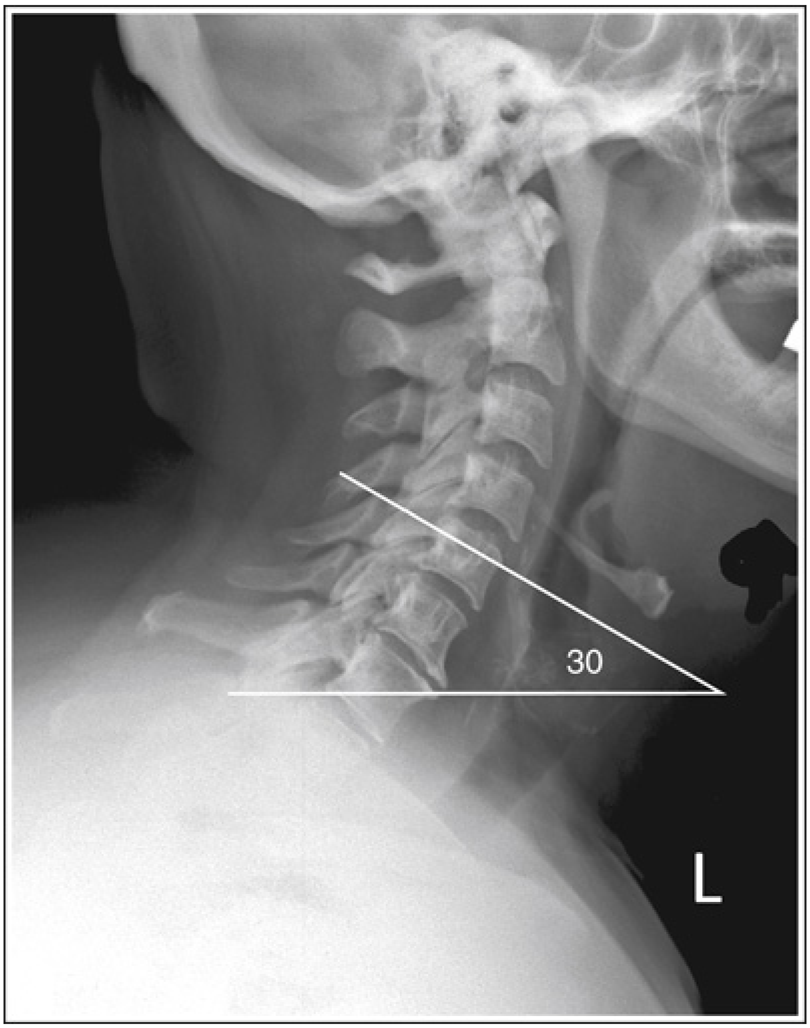


FIGURE 8.6 Lateral cervical vertebrae projection taken on a kyphotic patient.

Insufficient Cephalic CR Angulation

Misalignment of the CR and intervertebral disk spaces for an AP cervical projection results in closed disk spaces, distorted vertebral bodies, and projection of the spinous processes into the vertebral bodies. If a cephalic CR angulation is not used or is insufficiently angled, the resulting projection demonstrates closed intervertebral disk spaces, and each vertebra's spinous process is demonstrated within its vertebral body (see **Figs. 8.3** and **8.8**). This anatomic relationship also results if the head and upper cervical vertebrae are tilted (anteriorly) toward the x-ray tube for the examination.

Excessive Cephalic CR Angulation

If the CR is angled more than needed to align the CR parallel with the intervertebral disk spaces, or if the cervical vertebral column was extended posteriorly for the examination as with a kyphotic patient, the resulting projection demonstrates closed intervertebral disk spaces, with each vertebra's spinous process demonstrated within the inferior adjoining vertebral body, and elongated uncinate processes (see **Figs. 8.7** and **8.9**).

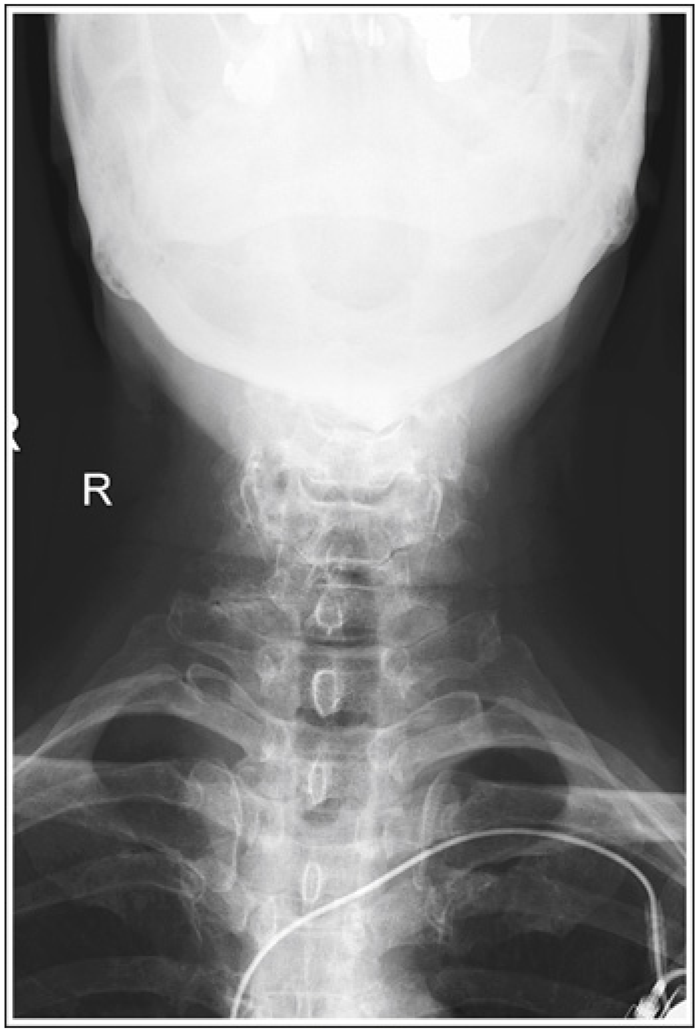


FIGURE 8.7 AP axial cervical vertebrae projection taken of a kyphotic patient.

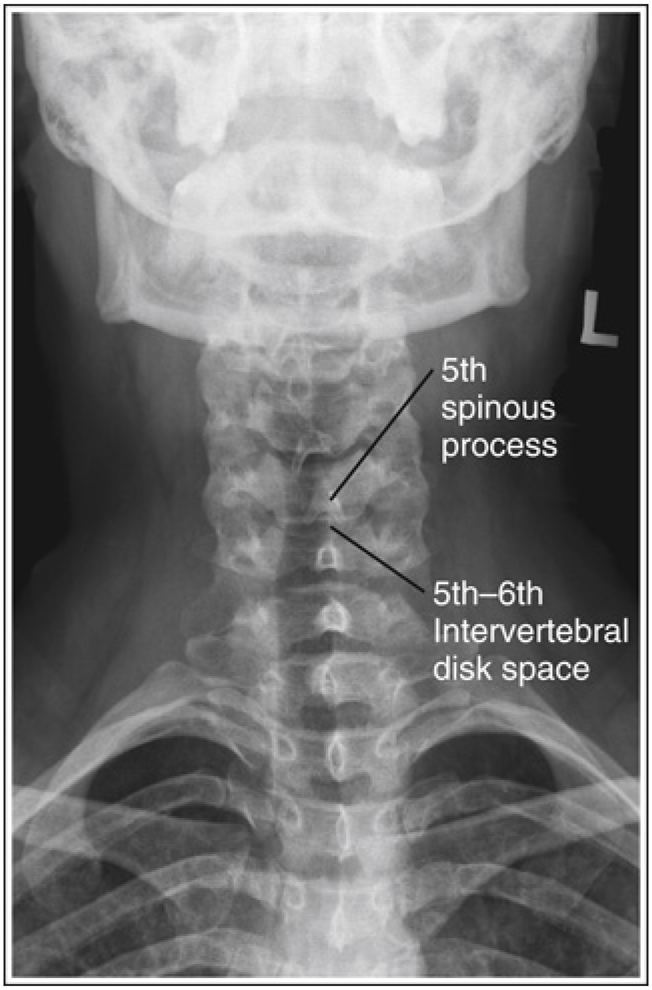


FIGURE 8.8 AP axial cervical vertebrae projection taken with insufficient cephalic CR angulation.

Mandibular Mentum Superior to Occipital Base

Accurate positioning of the occiput and mandibular mentum is achieved when the lower surface of the upper incisors and the tip of the mastoid process is aligned perpendicular to the IR (see **Fig. 8.2**). With this position, you might expect the mandible to be superimposed over the upper cervical vertebrae, but this will not be the case because the cephalad CR angulation used will project the mandible superiorly. Mispositioning of the occiput and mentum results in a projection demonstrating an obstructed upper cervical

vertebra. If the mandibular mentum is positioned superior to the occipital base (head tilted too far backward), the upper cervical vertebrae are superimposed over the occiput (**Fig. 8.10**).

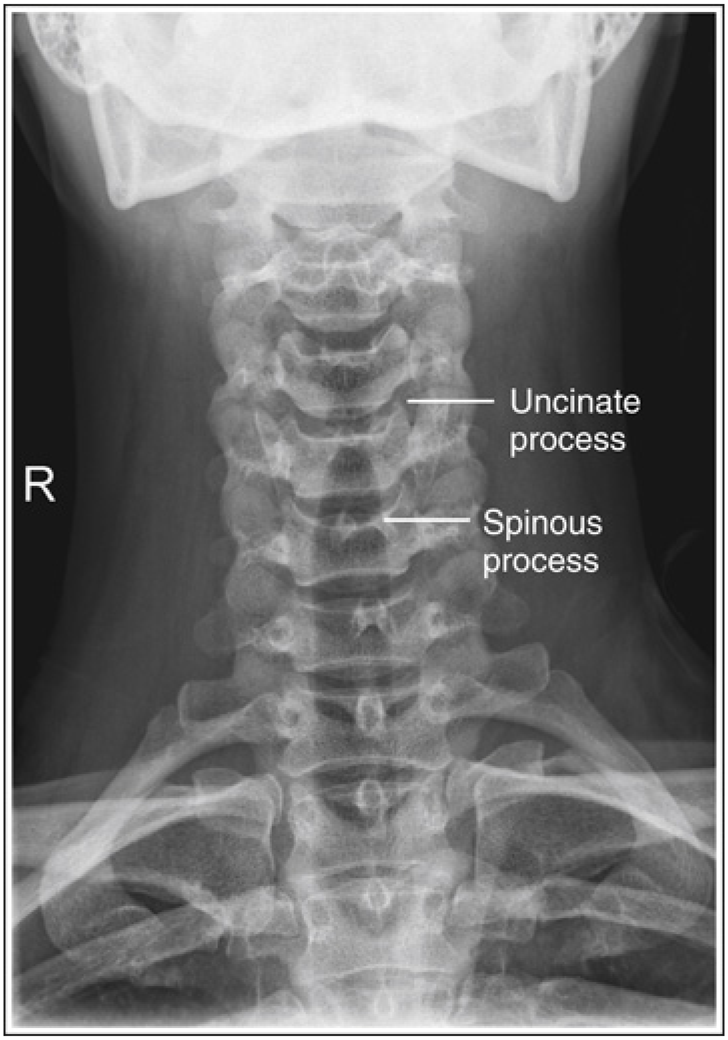


FIGURE 8.9 AP axial cervical vertebrae projection taken with excessive cephalic CR angulation.

Mandibular Mentum Inferior to Occipital Base

If the mandibular mentum is positioned inferior to the occipital base (chin tucked too far downward), it is superimposed over the superior cervical

vertebrae (**Fig. 8.11**).

Cervical Column and Exposure Field Alignment

Aligning the long axis of the cervical column with the long axis of the collimated field ensures that no lateral flexion of the cervical column is present and allows for tight collimation (see **Figs. 8.11** and **8.12**).

Cervical Trauma

When cervical vertebral projections are exposed on a trauma patient with suspected subluxation or fracture, obtain the AP axial projection with the patient positioned as is. Do not attempt to remove the cervical collar or adjust the head or body rotation, mandible position, or cervical column tilting. Such movement may result in greater injury to the vertebrae or spinal cord. Spinal cord injuries may occur from mishandling the patient after the initial injury has taken place.

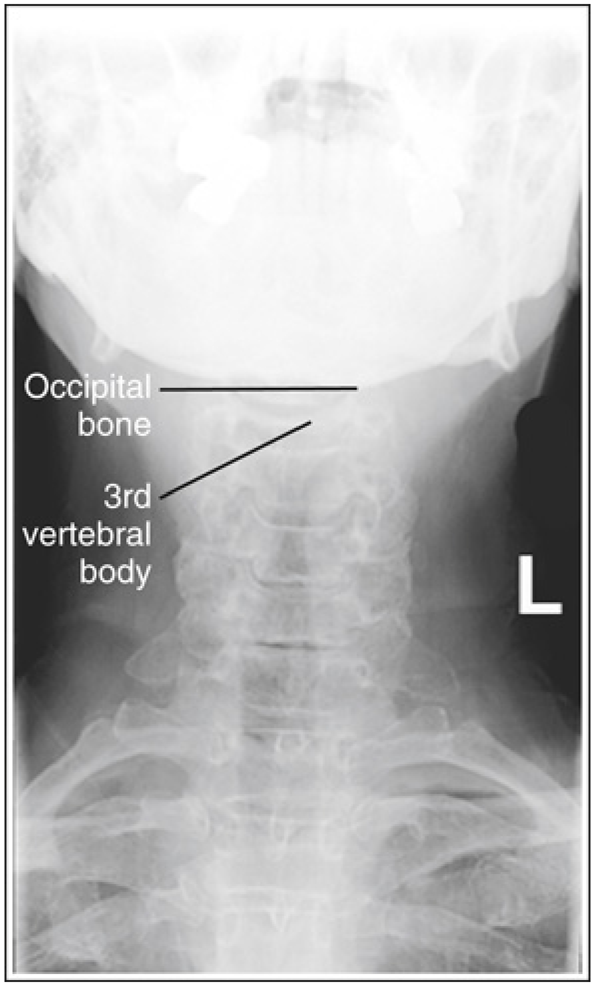


FIGURE 8.10 AP axial cervical vertebrae projection taken with the head tilted too far backward to align the upper incisors and mastoid tip perpendicular to the IR.

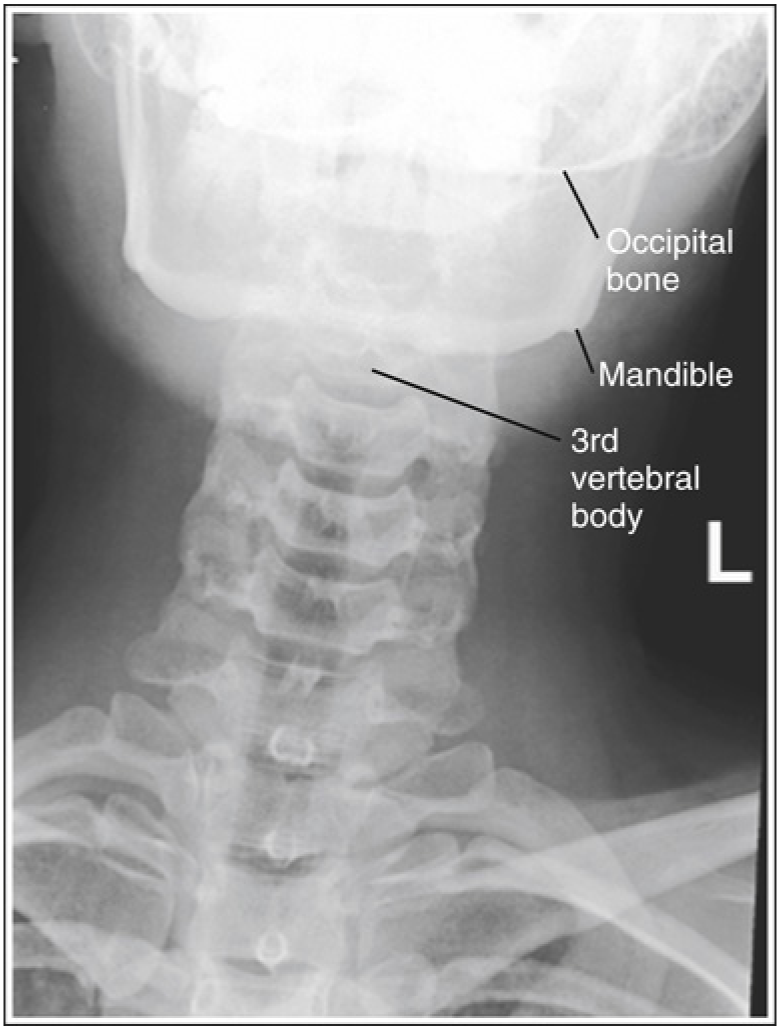


FIGURE 8.11 AP axial cervical vertebrae projection taken with the chin tucked too far to align the upper incisors and mastoid tip perpendicular to the IR and without the vertebral column aligned with the long axis of the IR.

FIGURE 8.12 AP axial cervical vertebrae projection taken with lateral flexion of the cervical column.

AP Axial Cervical Vertebrae Analysis Practice

IMAGE 8.1

Analysis

The anteroinferior aspects of the cervical bodies are obscuring the intervertebral disk spaces, and each vertebra's spinous process is demonstrated within its vertebral body. The CR angulation was insufficient to align it parallel with the intervertebral disk spaces. The mandible is superimposing the third cervical vertebrae. The chin was tucked too far downward.

Correction

Increase the degree of CR angulation and elevate the chin until the lower surface of the upper incisors and the mastoid tip is aligned perpendicular with the IR.

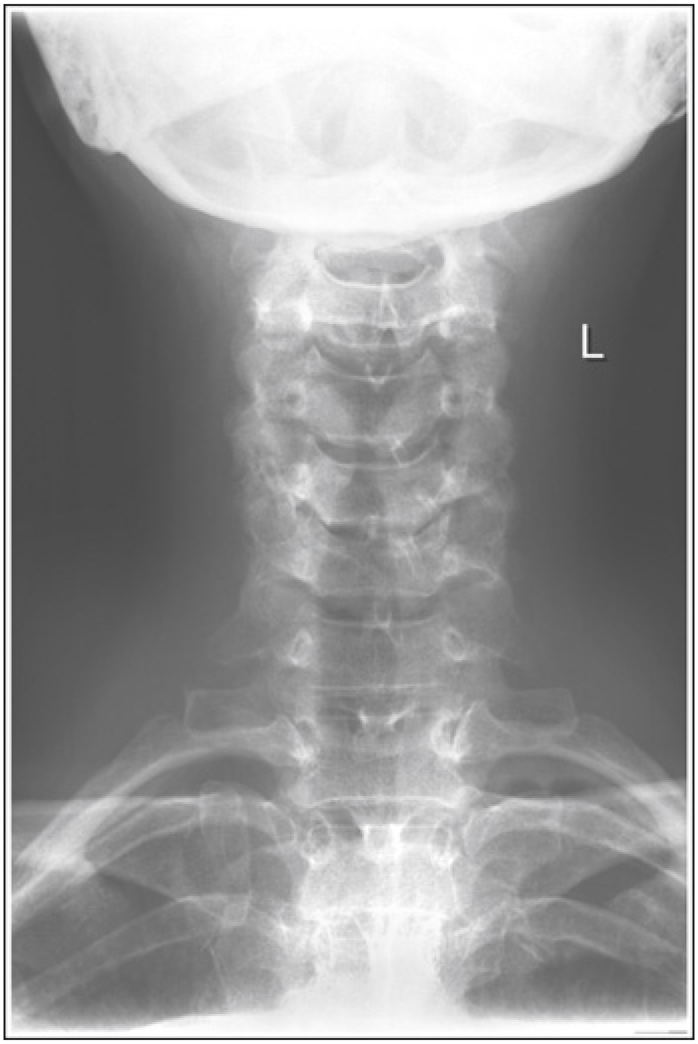


IMAGE 8.2

Analysis

The posteroinferior aspects of the cervical bodies are obscuring the intervertebral disk spaces, the uncinate processes are elongated, and each

vertebra's spinous process is demonstrated within the inferior adjoining vertebral body. The CR was angled too cephalically.

Correction

Decrease the degree of cephalic CR angulation.

Cervical Atlas and Axis: AP Projection (Open-Mouth Position)

See **Table 8.3** and **Figs. 8.13** and **8.14**.

Cervical Rotation

Rotation of the atlas and axis occurs when the head is turned away from an AP projection. On head rotation, the atlas pivots around the dens so that the lateral mass located on the side from which the face is turned is displaced anteriorly and the mass located on the side toward which the face is turned is displaced posteriorly. This displacement causes the space between the lateral mass and dens to narrow on the side from which the face is turned and to enlarge on the side toward which the face is turned (**Fig. 8.15**). As the amount of head rotation increases, the axis rotates in the same direction as the atlas, resulting in a shift in the position of its spinous process in the direction opposite that in which the face is turned. To determine how the face was turned, judge the distance between the mandibular rami and lateral masses. The side that demonstrates the greater distance is the side toward which the face was rotated.

Upper Incisor, Occipital Base, and CR Positioning

The dens and the atlantoaxial joint are located at the midsagittal plane, at a level 0.5 inch (1.25 cm) inferior to an imaginary line connecting the

mastoid tips. The goal of the AP open-mouth projection is to demonstrate the dens and atlantoaxial joint without occiput or without upper incisor (top teeth) superimposition. To accomplish this goal, the chin is tucked until an imaginary line connecting the lower surface of the upper incisors and the tip of the mastoid process is aligned perpendicular to the IR and the mouth is open as widely as possible. It may be necessary to position a small angled sponge beneath the head to maintain accurate head positioning, especially if the chin has to be tucked so much that it is difficult to open the mouth adequately. The sponge causes the upper incisors and mastoid tip to align perpendicularly without requiring as much chin-tucking. The lateral cervical projection in **Fig. 8.16** demonstrates how the upper incisors and occipital base are aligned when the incisors and mastoid tip are aligned perpendicular to the IR. By studying this projection, you might conclude that this positioning, with a perpendicular CR, would demonstrate the atlantoaxial joint space free of upper incisor and occiput superimposition, but the tip of the dens would be obscured, as shown in **Fig. 8.17**. This is because the upper incisors are positioned at a long object–IR distance (OID) and the magnification this causes must also be considered. In most patients, when the upper incisors and mastoid tip are aligned perpendicularly, magnification will cause the upper incisors to be demonstrated as much as 1 inch (2.5 cm) inferior to the occipital base (**Fig. 8.18**). For these magnified incisors to be projected superior to the dens, a 5-degree cephalic angle may be placed on the CR. If, instead of adjusting the CR angulation, the chin were tilted upward in an attempt to shift the upper incisors superiorly, the occipital base would simultaneously be shifted inferiorly, causing the dens and atlantoaxial joint to superimpose it (**Fig. 8.19**). If the occiput is positioned accurately superior to the dens, but the atlantoaxial joint is closed and the upper incisors are positioned too superiorly, the CR was

angled too cephalically. This positioning will also demonstrate the spinous process of the axis at the level of the third vertebral body (**Fig. 8.20**).

TABLE 8.3

AP, Anteroposterior; *CR*, central ray; *EAM*, external auditory meatus; *IR*, image receptor.

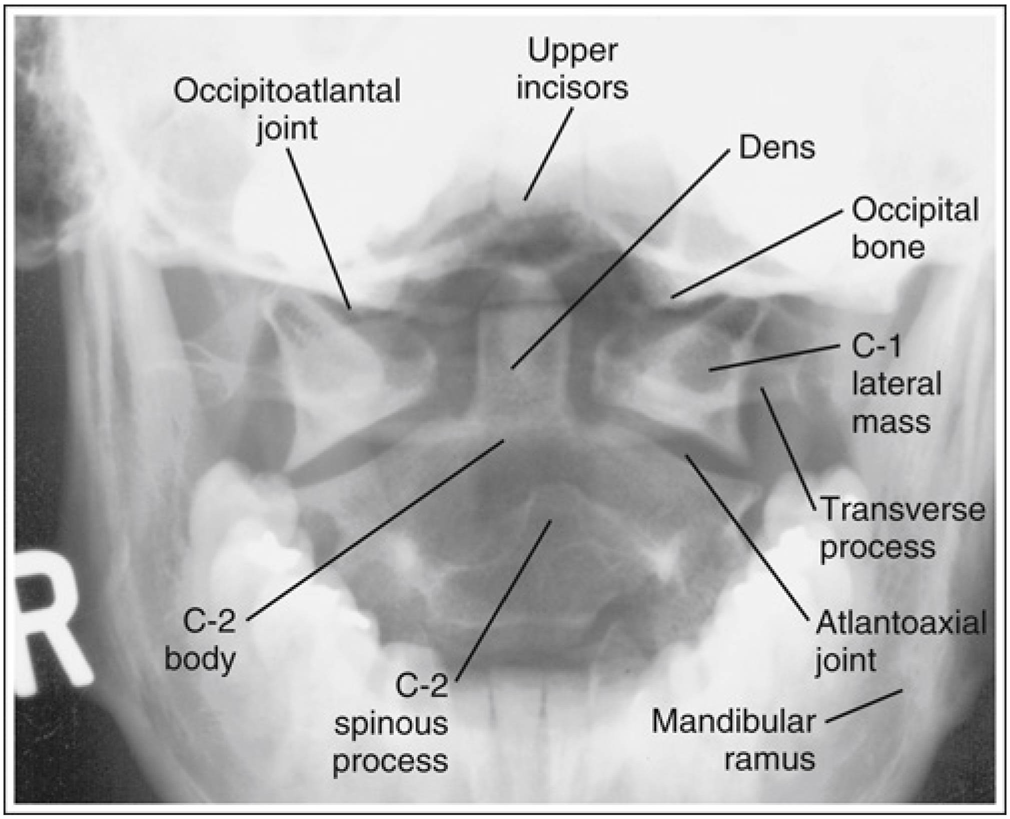


FIGURE 8.13 AP atlas and axis projection with accurate positioning.

FIGURE 8.14 Proper patient positioning for AP atlas and axis projection.

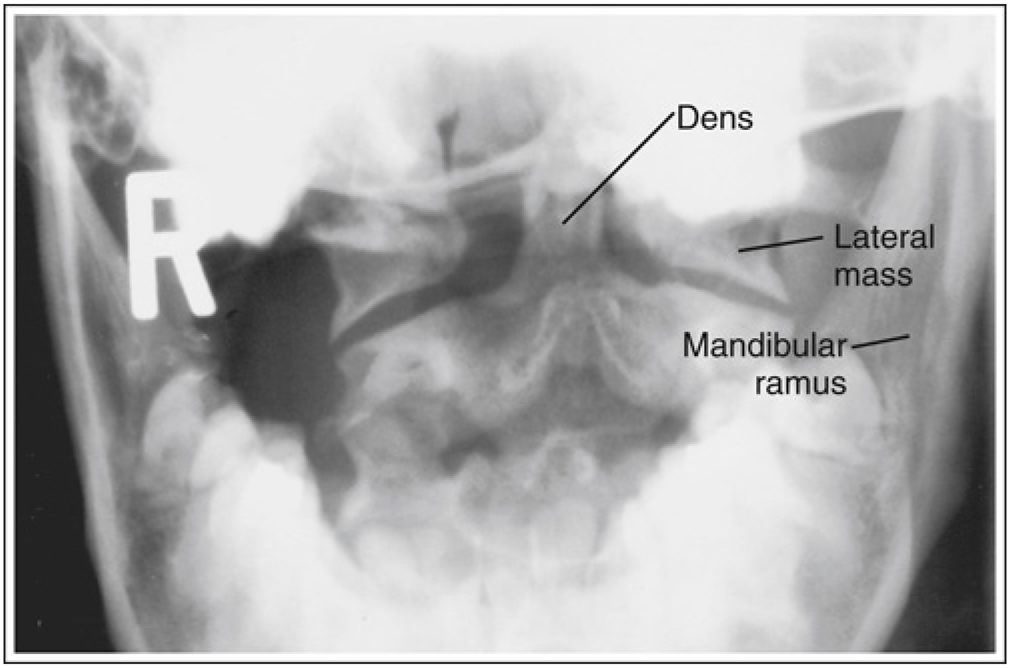


FIGURE 8.15 AP atlas and axis projection taken with the face rotated toward the right side.

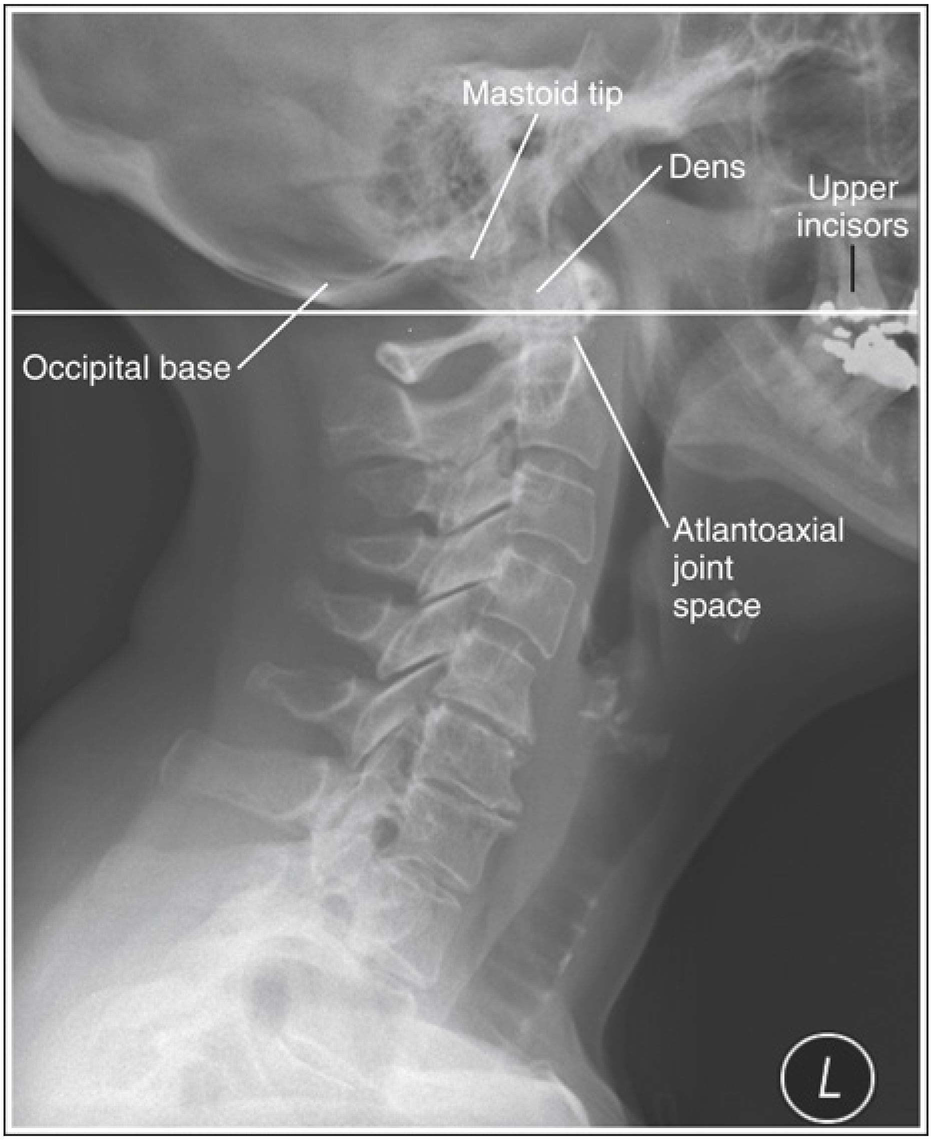


FIGURE 8.16 Lateral cervical vertebrae projection demonstrating upper incisor, dens, atlantoaxial joint space, and posterior occiput relationship.

FIGURE 8.17 AP atlas and axis projection taken with the upper incisors and mastoid tip aligned perpendicular to the IR and the CR angled 5 degrees cephalically.

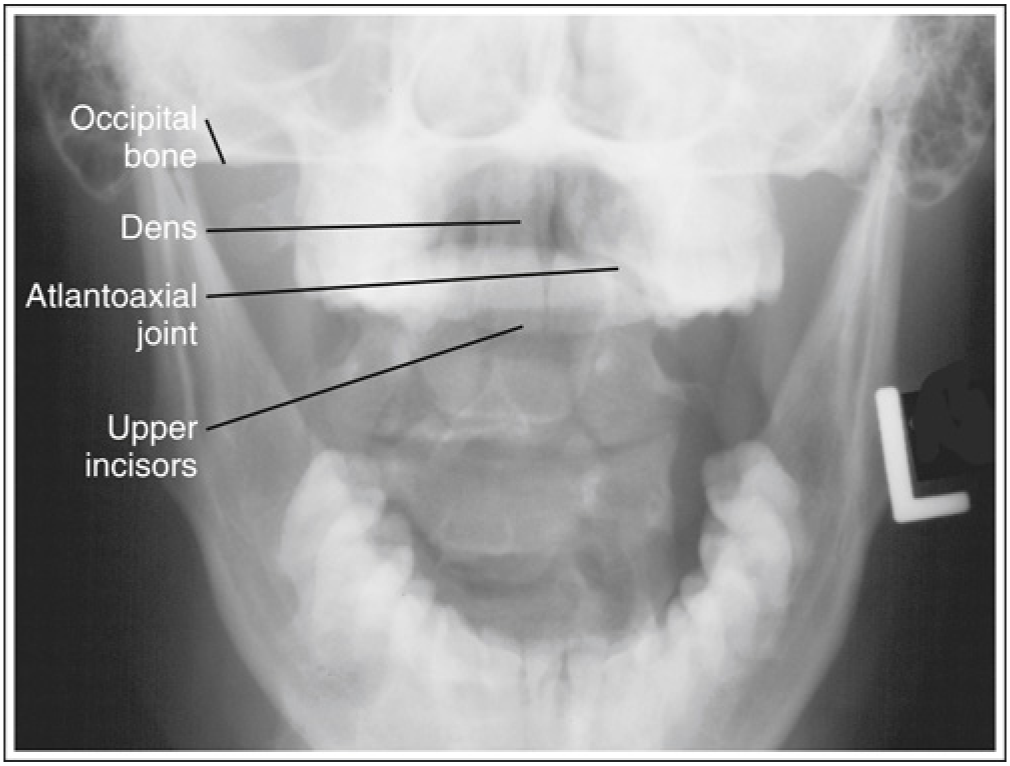


FIGURE 8.18 AP atlas and axis projection taken with the upper incisors and mastoid tip aligned perpendicular to the IR and a perpendicular CR.

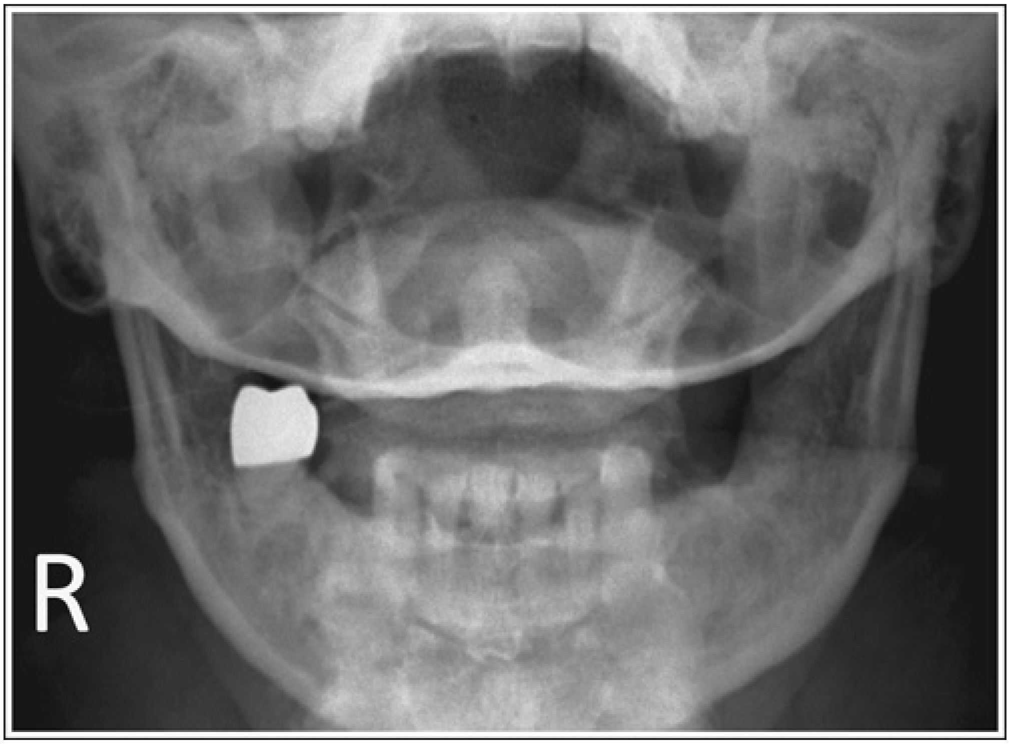


FIGURE 8.19 AP atlas and axis projection taken with the head tilted too far backward to align the upper incisors and mastoid tip perpendicular to the IR.

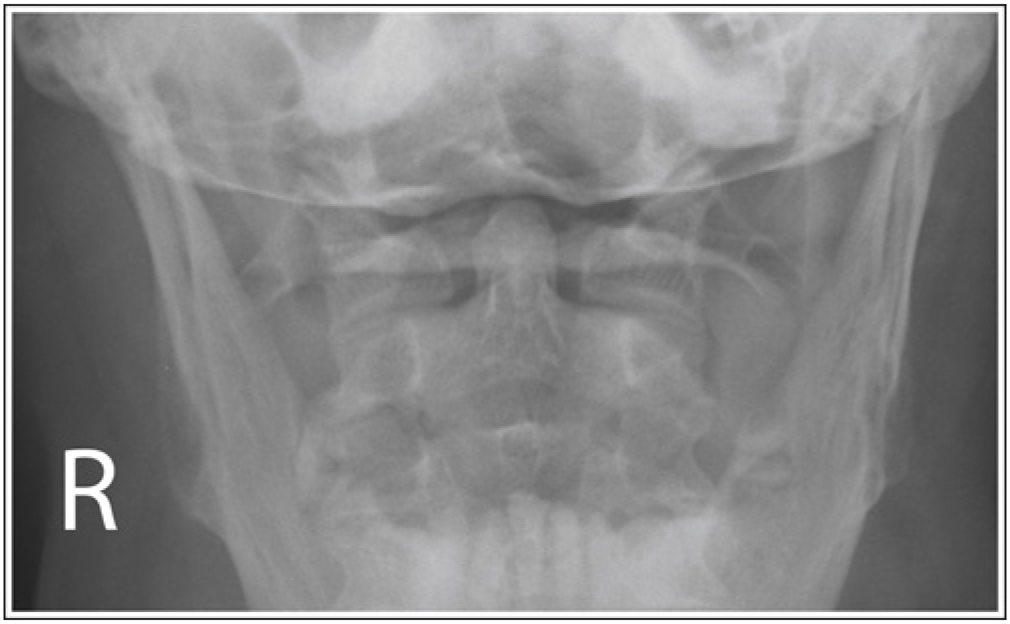


FIGURE 8.20 AP atlas and axis projection taken with the CR angled too cephalically.

CR Alignment for Cervical Trauma

For the dens and atlantoaxial joint to be demonstrated without incisor or occiput superimposition when imaging a trauma patient, the direction of the CR must be changed from the standard position. A trauma patient's head and neck cannot be adjusted until the initial projections have been cleared by the radiologist, because of the potential of this movement to cause increased injury, and the cervical collar worn by these patients tilts the chin upward. In this position, the line connecting the incisors and mastoid tip is at approximately a 10-degree caudal angulation and the upper incisors are at an angle with the CR that will result in less magnification of them, because of foreshortening on the resulting projection. Because of this upper chin tilting, the occipital base is positioned directly beneath the dens and atlantoaxial joint space and they will superimpose it if the CR is not angled caudally to project them inferiorly (Fig. 8.21). The infraorbitomeatal line

(IOML; line connecting the inferior orbital rim and the external ear opening) is easy to access in a patient wearing a cervical collar, and when the CR is aligned with it, it can be used to determine the needed angulation. Once the CR is aligned with the IOML, attempt to get the patient to drop the lower jaw. Do not adjust head rotation or tilting. If the cervical collar allows the lower jaw to move without elevating the upper jaw, instruct the patient to drop the lower jaw. If the cervical collar prevents lower jaw movement without elevating the upper jaw, instruct the patient about the importance of holding the head and neck perfectly still; then have the ordering physician remove the front of the cervical collar so that the patient can drop the jaw without adjusting the head or neck position (**Fig. 8.22**). After the jaw is dropped, align the CR to the midsagittal plane at a level 0.5 inch (1.25 cm) inferior to the lower surface of the upper incisors. Immediately after the projection is taken, the physician should return the front of the cervical collar to its proper position.

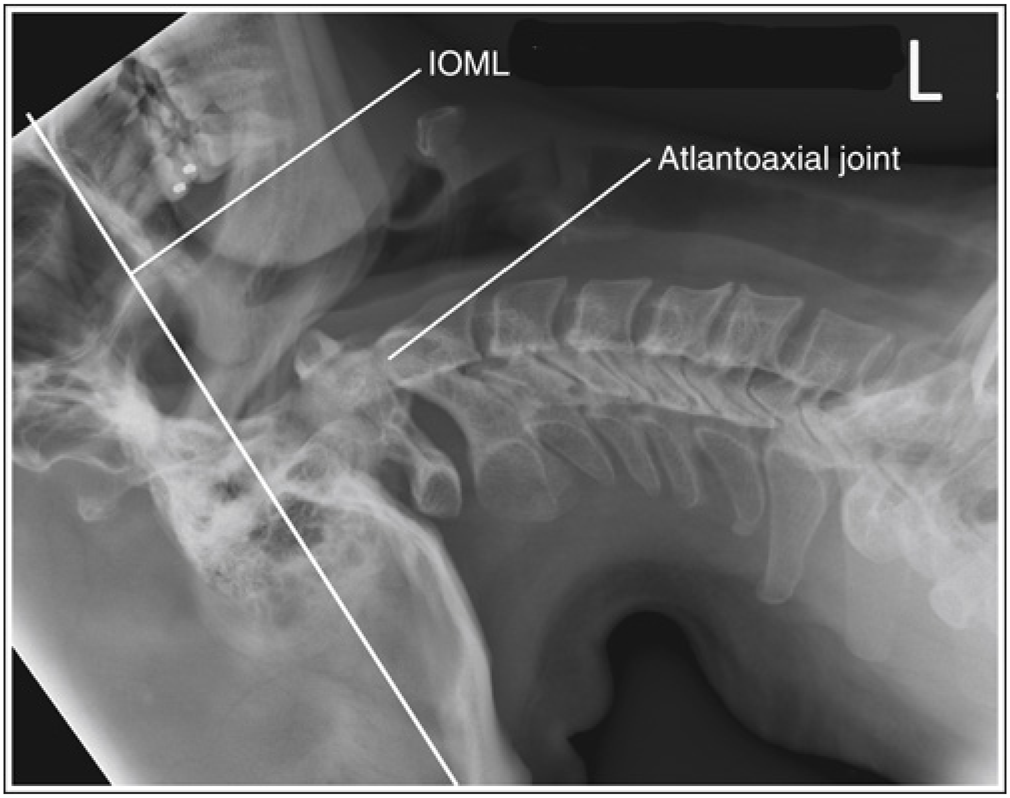


FIGURE 8.21 Lateral cervical vertebrae projection to visualize IOML, dens, and atlantoaxial joint alignment for trauma AP atlas and axis projection.

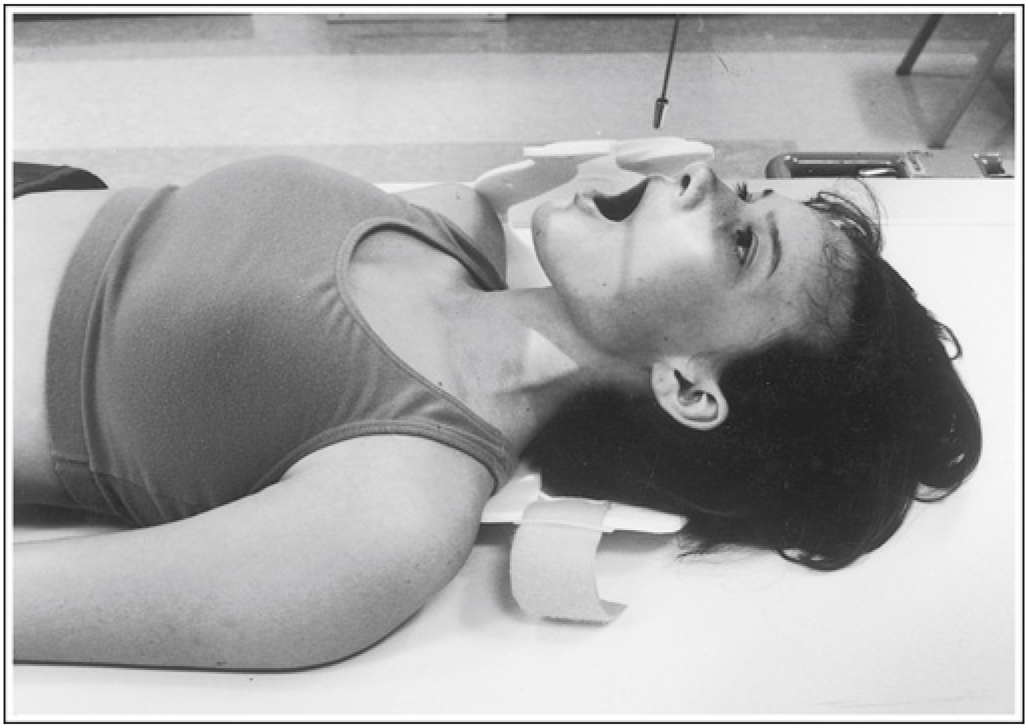


FIGURE 8.22 Proper patient positioning for AP atlas and axis projection taken to evaluate trauma.

(Fig. 8.23).

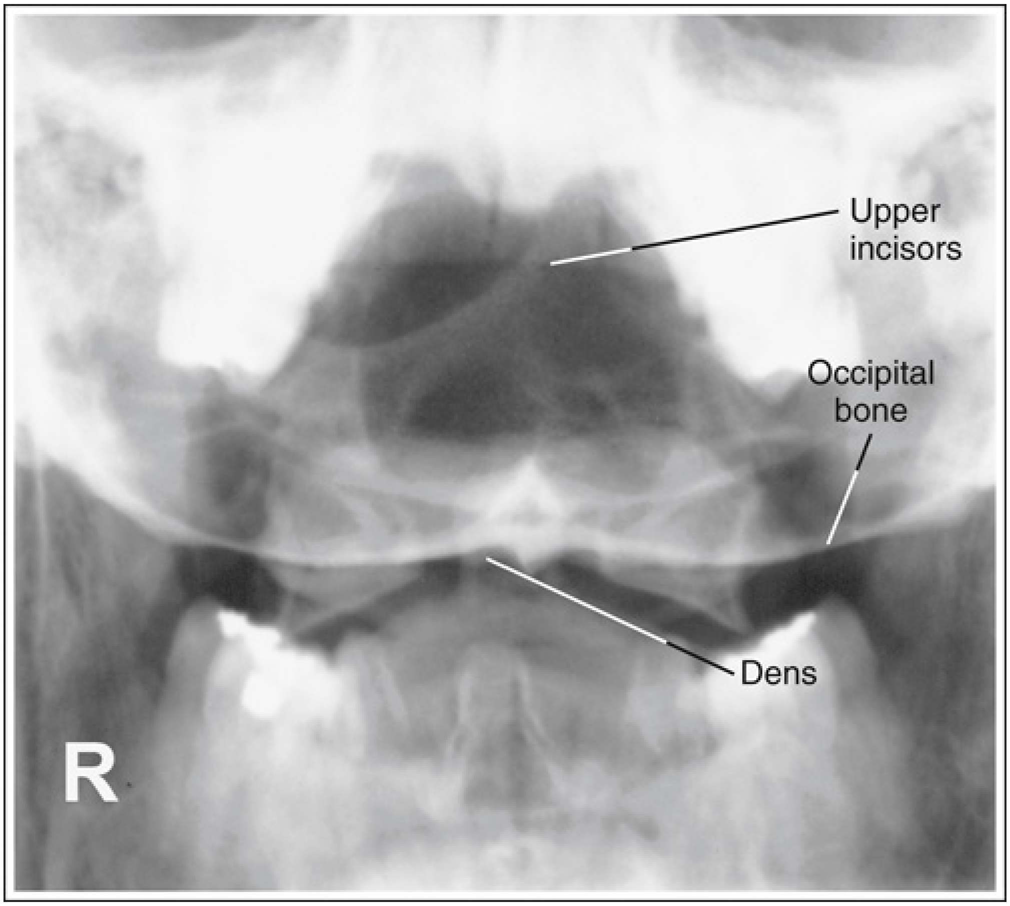


FIGURE 8.23 AP atlas and axis projection taken with insufficient caudal CR angulation.

Trauma: Insufficient Caudal CR Angulation

For trauma positioning, insufficient caudal angulation causes the upper incisors to be demonstrated superior to the dens and the dens to be superimposed over the occipital base (**Fig. 8.23**).

Trauma: Excessive Caudal CR Angulation

If the CR was angled too caudally, the occipital base is demonstrated superior to the dens and the upper incisors are superimposed over the dens (**Fig. 8.24**).

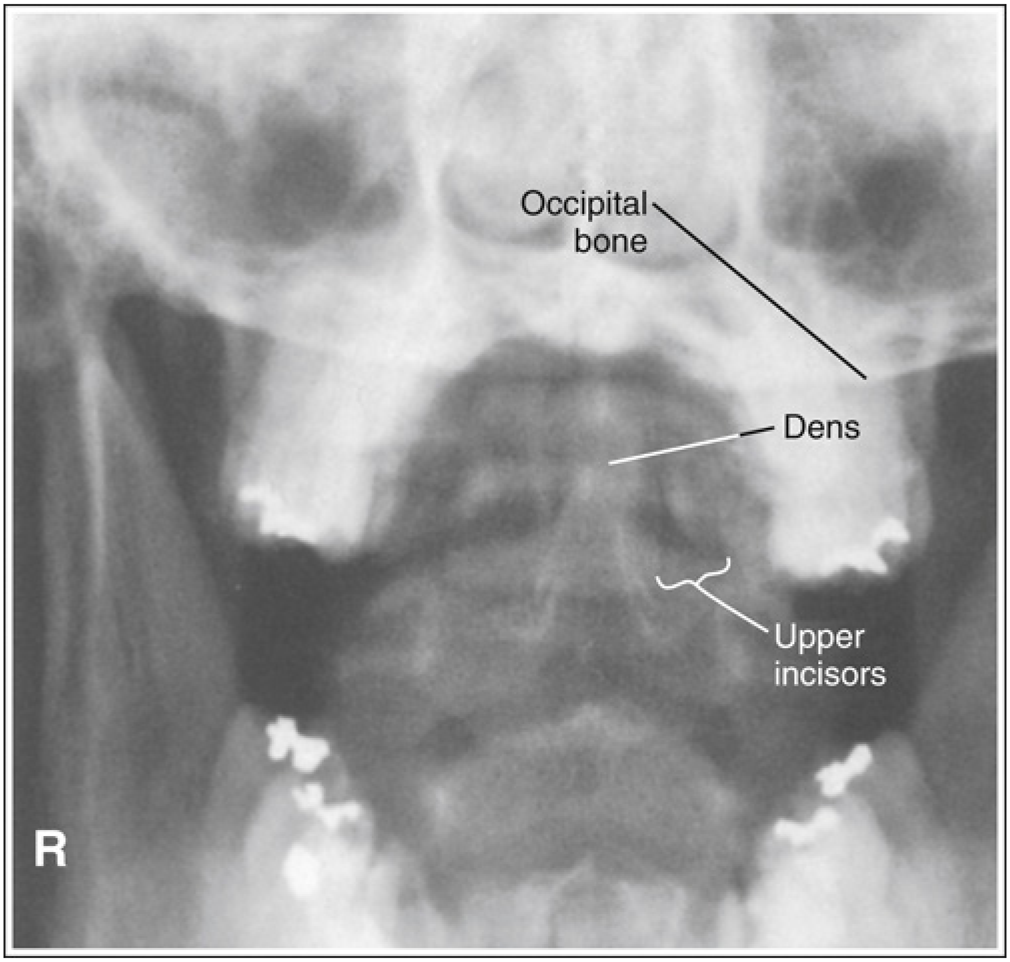


FIGURE 8.24 AP atlas and axis projection taken with excessive caudal CR angulation.

AP Cervical Atlas and Axis Analysis Practice

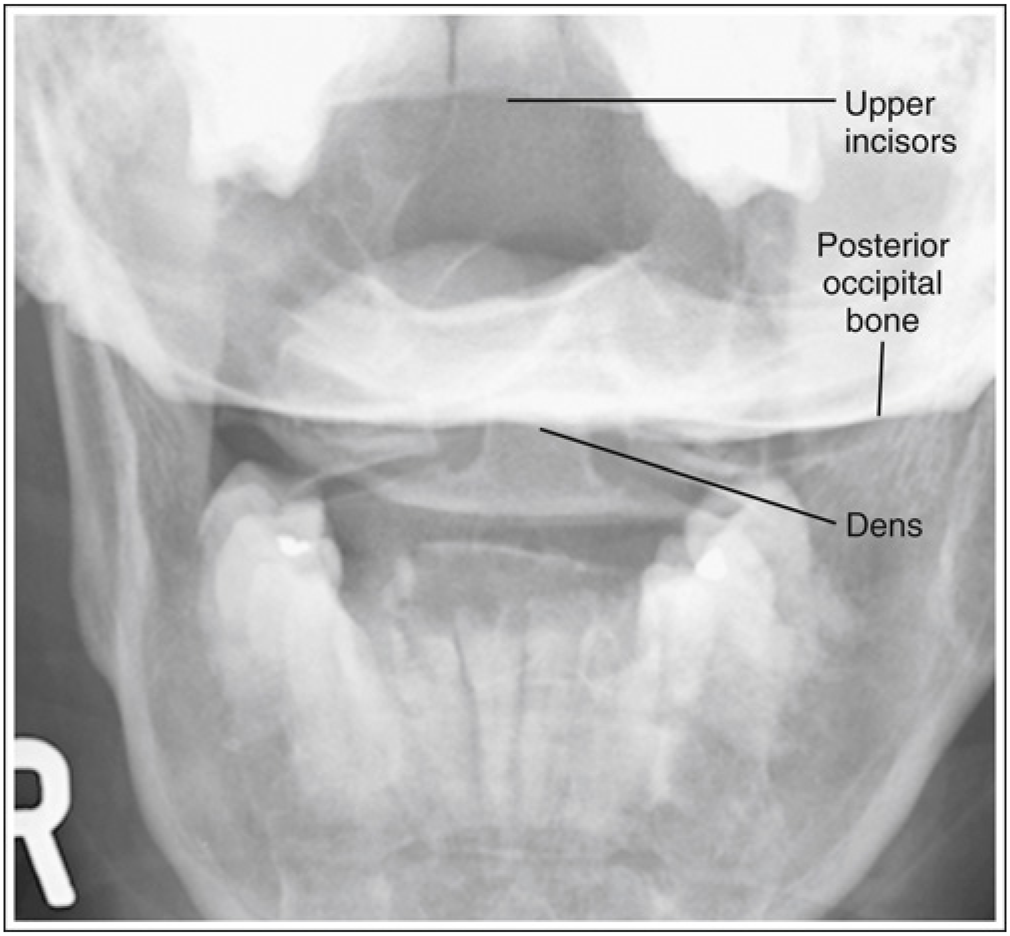


IMAGE 8.3

Analysis

The dens is superimposed over the occipital base and the upper incisors are demonstrated superior to the occipital base. The chin was elevated. The distances from the atlas's lateral masses to the dens and from the mandibular rami to the dens are narrower on the left side than on the right side. The face was rotated toward the right side.

Correction

Lower the upper incisors until the lower edge of the upper incisors and mastoid tip is aligned perpendicular with the IR, and rotate the face toward

the left side until it is forward.

IMAGE 8.4

Analysis

The distances from the atlas's lateral masses to the dens and from the mandibular rami to the dens are narrower on the left side than on the right side. The face was rotated toward the right side. The upper incisors are demonstrated inferior to the occipital base, obscuring the dens and atlantoaxial joint space. The CR was not angled 5 degrees cephalically.

Correction

Rotate the face toward the left side until it is forward and angle the CR 5 degrees cephalically.

Cervical Vertebrae: Lateral Projection

See **Table 8.4** and **Figs. 8.25** and **8.26**.

Prevertebral Fat Stripe Visualization

The soft tissue structure of interest on a lateral cervical projection is the prevertebral fat stripe. It is located anterior to the cervical vertebrae and is visible on correctly exposed lateral cervical projections with accurate positioning (**Fig. 8.27**). The reviewer evaluates the distance between the anterior surface of the cervical vertebrae and the prevertebral fat stripe. Abnormal widening of this space is used for the detection and localization of fractures, masses, and inflammation.

Cervical and Cranial Rotation

Cervical rotation can be detected on a lateral cervical projection by evaluating each vertebra for anterior and posterior pillar superimposition and for zygapophyseal joint superimposition. When the torso or the cranium is rotated, the pillars and zygapophyseal joints on one side of the vertebra move anterior to those on the other side and one mandibular ramus is anterior to the other (**Figs. 8.28** and **8.29**). Because the two sides of the vertebrae are mirror images, it is very difficult to determine from a rotated lateral cervical projection which side of the patient is rotated anteriorly and which is rotated posteriorly. The magnification of the mandible situated farther from the IR may provide a moderately reliable clue.

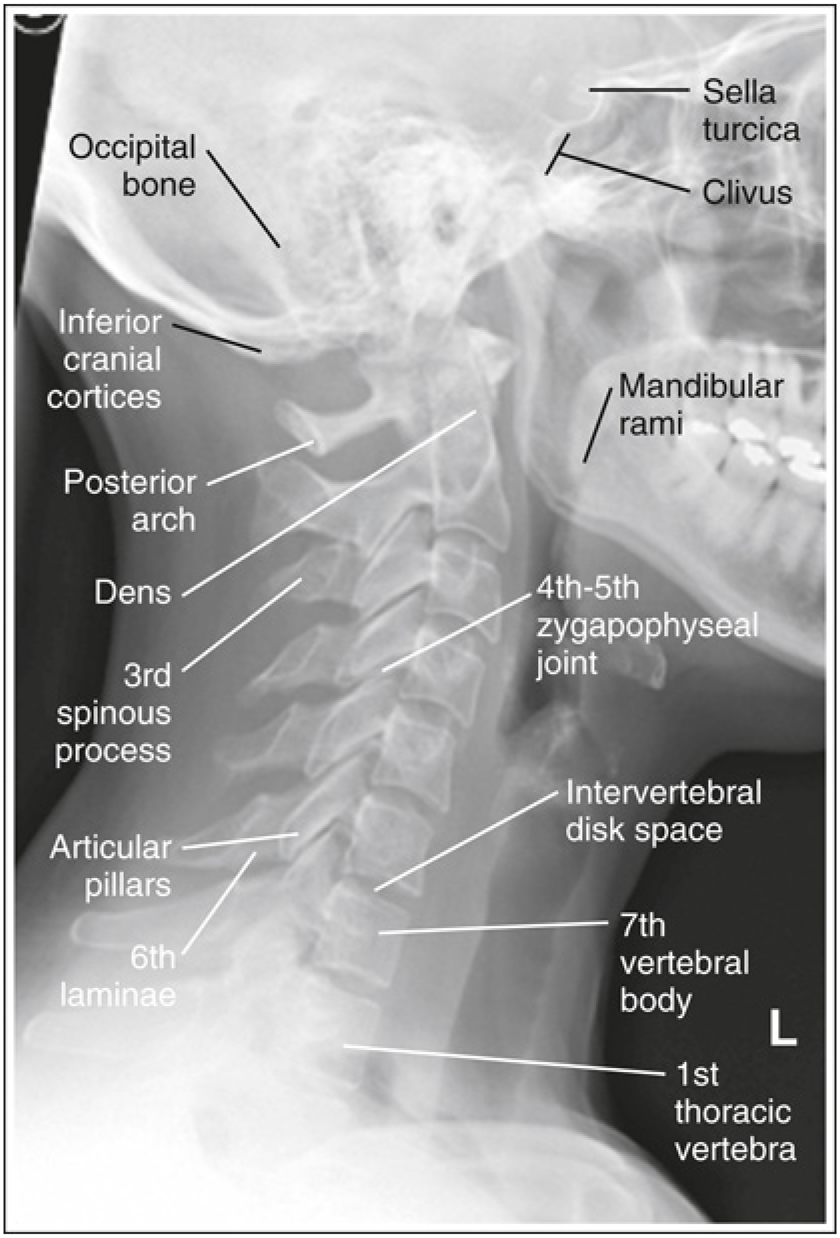


FIGURE 8.25 Lateral cervical vertebrae projection with accurate positioning.

FIGURE 8.26 Proper patient positioning for lateral cervical vertebrae projection.

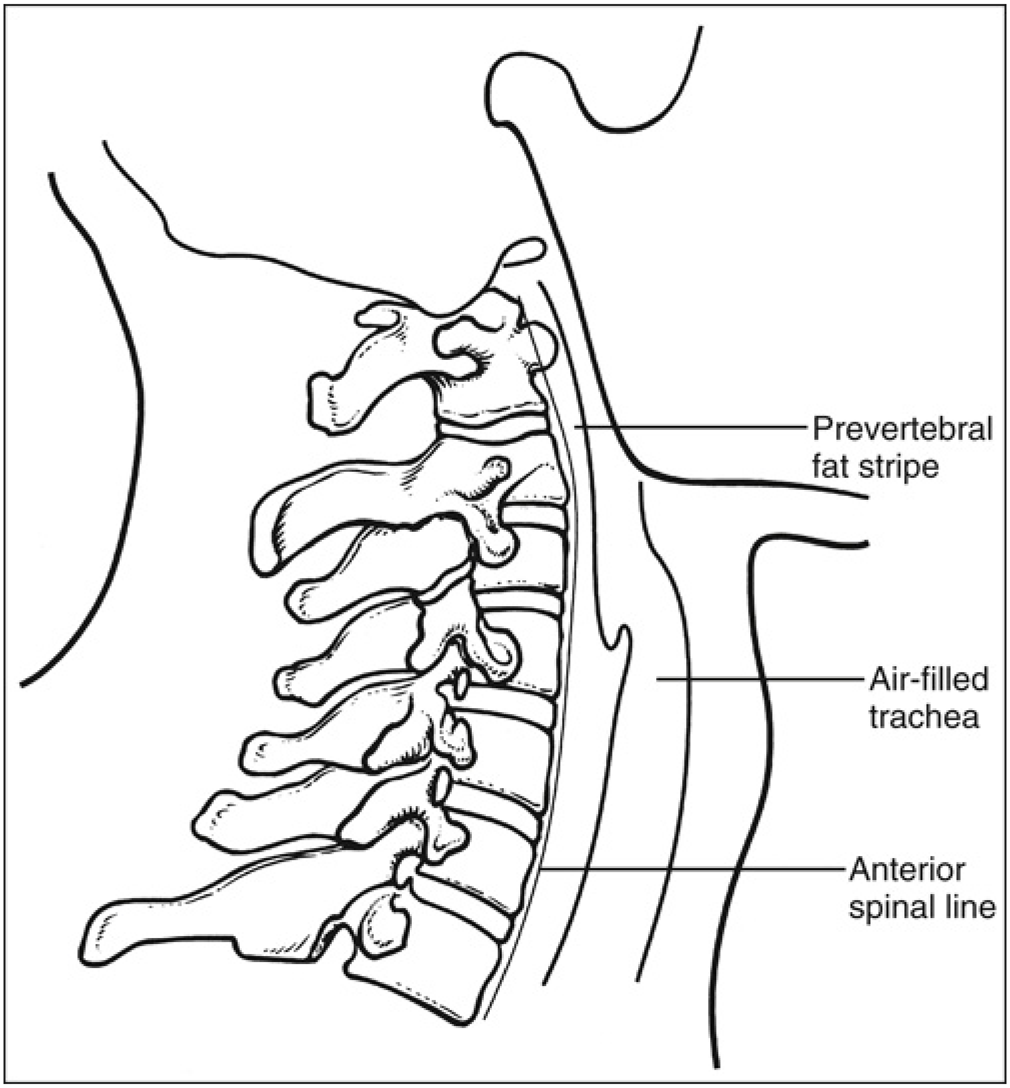


FIGURE 8.27 Location of prevertebral fat stripe.

TABLE 8.4

AML, Acanthiomeatal line; *CR*, central ray; *EAM*, external auditory meatus; *IPL*, interpupillary line; *IR*, image receptor; *SID*, source–image receptor distance.

Lateral Flexion of Cervical Vertebrae

Lateral flexion of the cervical vertebrae results when the interpupillary line (IPL) is not aligned perpendicular to the IR and the shoulders are not placed on the same horizontal plane, resulting in an inferosuperior misalignment of the vertebrae.

- *If the head and upper cervical vertebral column were tilted away from the IR*, there is a separation between the right and left articular pillars and zygapophyseal joints of the upper cervical vertebrae, the inferior cortices of the cranium and the mandibular rami are demonstrated without superimposition, and the posterior arch of C1 remains in profile (**Fig. 8.30**).
- *If the head was tilted toward the IR*, there is a separation between the right and left articular pillars and zygapophyseal joints of the upper cervical vertebrae, the inferior cortices of the cranium and the mandibular rami are demonstrated without superimposition, and the vertebral foramen of C1 is demonstrated (**Fig. 8.31**).
- *If the cranium is accurately positioned and the shoulders are not positioned on the same horizontal plane*, there is a separation between the right and left articular pillars and zygapophyseal joints of the lower cervical vertebrae (**Fig. 8.32**). It is not possible to determine whether the right or left shoulder was positioned lower when such a projection has been obtained, but it is most common for the shoulder positioned adjacent to the IR to be the lower one as the patient leans toward the IR.

FIGURE 8.28 Lateral cervical vertebrae projection taken with the patient's right side rotated slightly posteriorly.

FIGURE 8.29 Lateral cervical vertebrae projection taken with the patient rotated.

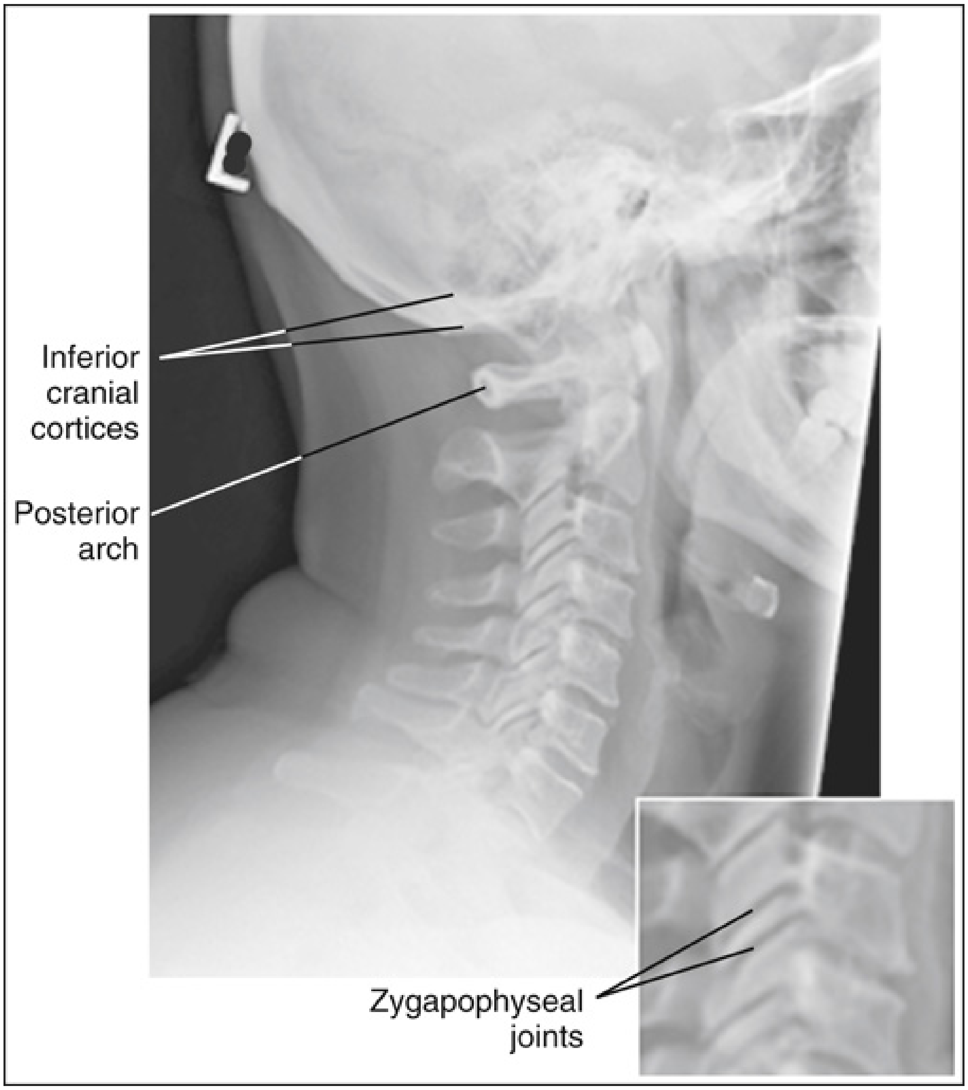


FIGURE 8.30 Lateral cervical vertebrae projection taken with the head and upper cervical vertebral column tilted away from the IR.

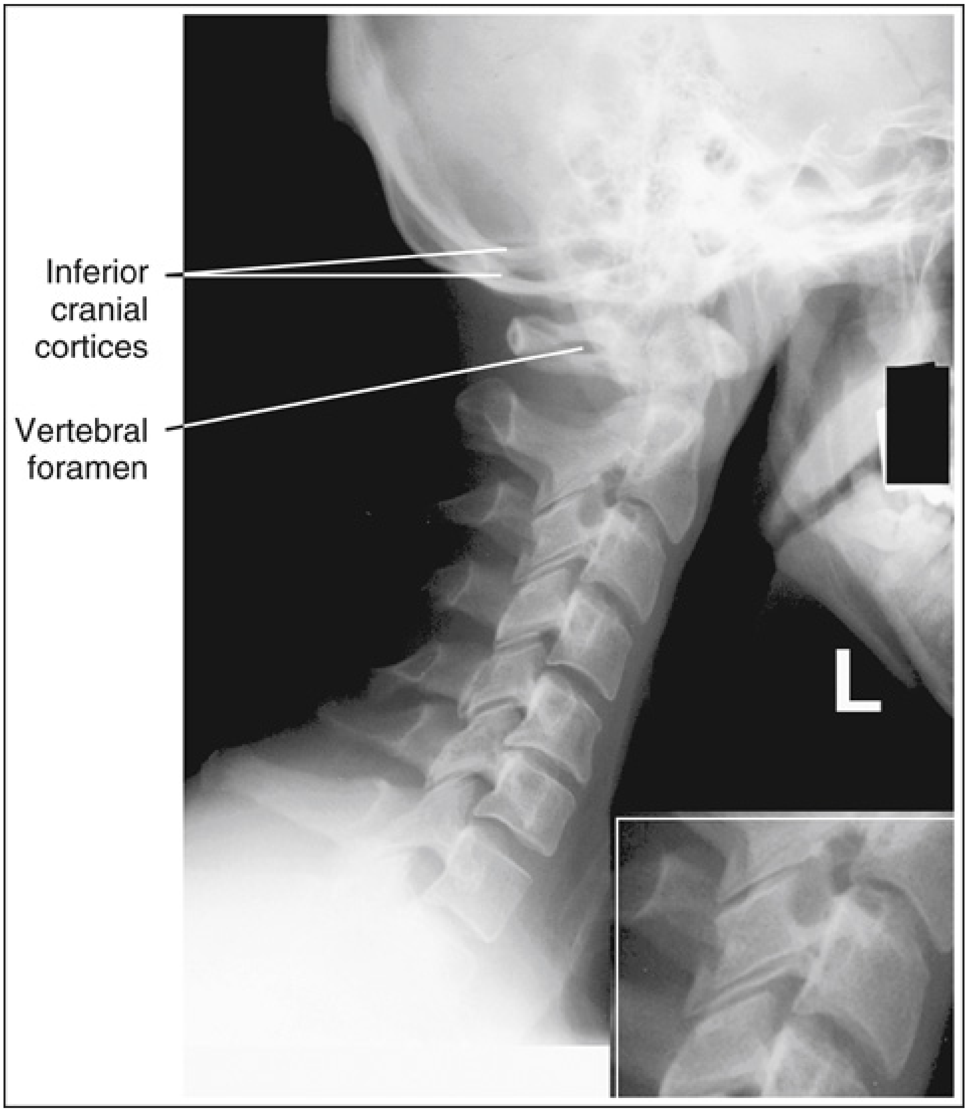


FIGURE 8.31 Lateral cervical vertebrae projection taken with the head and upper cervical vertebral column tilted toward the IR and without the chin elevated enough to place the acanthiomeatal line parallel with the floor.

FIGURE 8.32 Lateral cervical vertebrae projection taken without the chin elevated enough to place the acanthiomeatal line parallel with the floor and the shoulders not positioned on the same horizontal plane.

Poor AML Alignment

If the chin was not adequately elevated to position the acanthiomeatal line (AML) parallel with the floor, one or both of the mandibular rami are superimposed over the bodies of C1 and/or C2 (see **Fig. 8.32**).

Evaluating AP Cervical Vertebral Mobility

Flexion and extension lateral projections are obtained to evaluate AP vertebral mobility.

For Flexion

Instruct the patient to tuck the chin into the chest as far as possible (**Fig. 8.33**). For patients who demonstrate extreme degrees of flexion, it may be necessary to place the IR crosswise to include the entire cervical column on the same projection. Such a projection should meet all the analysis requirements listed for a neutral lateral projection, except that the long axis demonstrates forward bending (**Fig. 8.34**).

For Extension

Instruct the patient to extend the chin up and backward as far as possible (**Fig. 8.35**). Such a projection should meet all the analysis requirements listed for a neutral lateral projection, except that the long axis demonstrates backward bending (**Fig. 8.36**). If the lateral projection is used with the patient in flexion or extension, an arrow pointing in the direction the neck is moving or a flexion or extension marker should be included to indicate the direction of neck movement.

FIGURE 8.33 Patient positioning for lateral cervical vertebrae projection with hyperflexion.

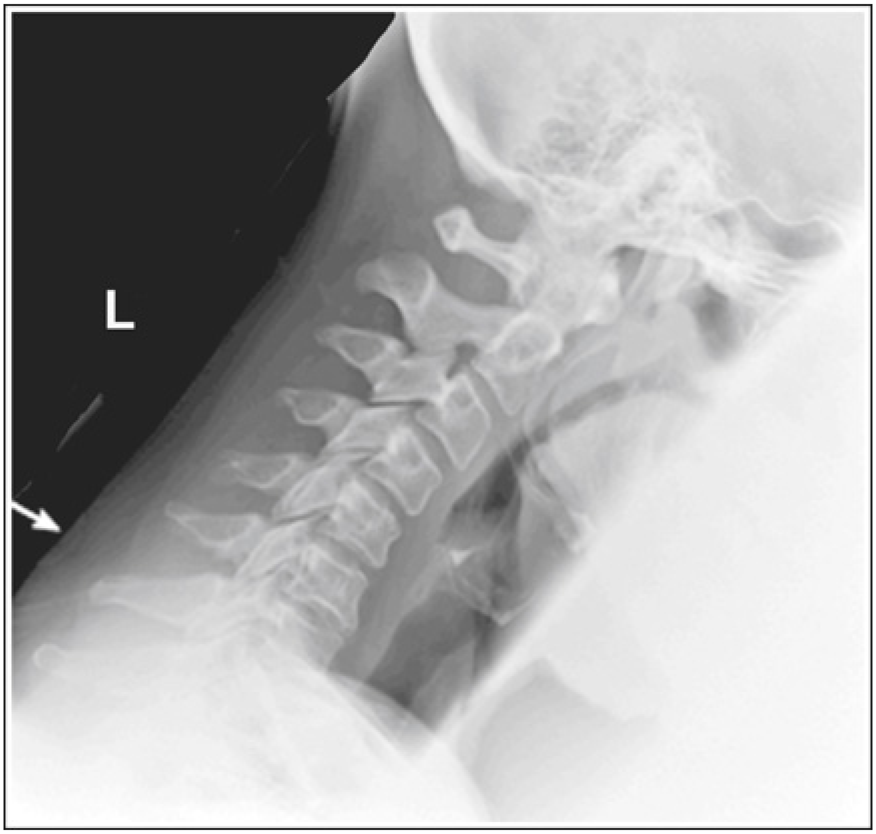


FIGURE 8.34 Lateral cervical vertebrae projection taken with the patient in hyperflexion.

Demonstration of C7 and T1 Vertebrae

The seventh cervical vertebra and first thoracic vertebra are located at the level of the shoulders. This location makes it difficult to demonstrate them because of the great difference in lateral thickness between the neck and the shoulders. The best method to demonstrate C7 is to have the patient hold 5- or 10-lb weights on each arm to depress the shoulders and attempt to move them inferior to C7. Weights are best placed on each arm at the elbow rather than in each hand, because sometimes the shoulders will elevate and elbows bend when weights are placed in the hands, allowing the weight to be distributed across these structures instead of pulling the shoulders down. Without weights, it is often difficult to demonstrate more than six cervical

vertebrae (see **Figs. 8.28** and **8.37**). Taking the projection on expiration also aids in lowering the shoulders. If even after using weights to depress the shoulders C7 cannot be demonstrated in its entirety, a special projection known as the lateral cervicothoracic projection (Twining method) should be taken and is described later in this chapter.

FIGURE 8.35 Patient positioning for lateral cervical vertebrae projection with hyperextension.

FIGURE 8.36 Lateral cervical vertebrae projection taken with the patient in hyperextension.

FIGURE 8.37 Lateral cervical vertebrae projection taken without adequate shoulder depression.

Importance of Including the Clivus

The clivus, a slanted structure that extends posteriorly off the sella turcica, and the dens should be included on a lateral cervical projection as they are used by the reviewer to determine cervical injury. A line drawn along the clivus should point to the tip of the dens on the normal upper lateral cervical vertebral projection (see **Fig. 8.26**).

Cervical Trauma Positioning

When cervical vertebral projections are taken of a trauma patient with suspected subluxation or fracture, take the lateral projection with the patient's position left as is. Do not attempt to remove the cervical collar or adjust head or body rotation, mandible position, or vertebral tilting. This might result in increased injury to the vertebrae or spinal cord. A trauma lateral cervical vertebral projection is obtained by placing a lengthwise IR against the shoulder and directing a horizontal beam to the cervical vertebrae (**Fig. 8.38**). Depress the shoulders by having a qualified assistant, with the consent of a physician, pull down on the arms while the projection is taken. To accomplish this, instruct an assistant to wear a protection apron and stand at the end of the imaging table or stretcher, with the patient's feet resting against the assistant's abdomen and the assistant's hands wrapped around the patient's wrists. The assistant should slowly pull on the patient's arms until the shoulders are moved inferiorly as much as possible. Such a projection should meet as many of the analysis requirements listed for a nontrauma lateral projection as possible without moving the patient.

FIGURE 8.38 Proper patient positioning for lateral cervical vertebrae projection taken to evaluate trauma.

Lateral Cervical Vertebrae Analysis Practice

IMAGE 8.5

Analysis

The articular pillars and zygapophyseal joints on one side of the patient are situated anterior to those on the other side. The patient was rotated.

Correction

Rotate the patient until the midcoronal plane is aligned perpendicular to the IR.

IMAGE 8.6

Analysis

The articular pillars and zygapophyseal joints on one side of the patient are situated anterior to those on the other side. The patient was rotated. The cranial and mandibular cortices are accurately aligned, and the mandibular

rami are superimposed over the body of C2. The chin was not adequately elevated.

Correction

Rotate the patient until the midcoronal plane is aligned perpendicular to the IR and elevate the chin until the AML is aligned parallel with the floor.

IMAGE 8.7

Analysis

The inferior cortices of the cranium and mandible are demonstrated without superimposition, the vertebral foramen of C1 is visualized, and the right and

left articular pillars and zygapophyseal joints demonstrate a superoinferior separation. The head and upper cervical vertebrae were tilted toward the IR.

Correction

Tilt the head away from the IR until the IPL is aligned perpendicular to the IR.

Cervical Vertebrae: PA or AP Axial Oblique Projection (Anterior and Posterior Oblique Positions)

See **Table 8.5** and Figs. **8.39**–**8.42**.

Insufficient Cervical Obliquity

If the cervical vertebral obliquity is less than 45 degrees, the intervertebral foramina are narrowed or obscured and the pedicles of interest are foreshortened (**Fig. 8.43**).

Excessive Cervical Obliquity

If the cervical vertebrae are rotated more than 45 degrees, the pedicles of interest are partially foreshortened and the opposite pedicles are aligned with the midline of the vertebral bodies, and the zygapophyseal joints that are demonstrated without vertebral body superimposition are demonstrated in profile (**Fig. 8.44**). Because it is possible for the upper and lower cervical vertebrae to be rotated to different degrees on the same projection, one needs to evaluate the entire cervical vertebrae for proper rotation (**Fig. 8.45**).

IPL Line Alignment

The distances demonstrated between the inferior cortical outlines of the cranium and the mandibular rami are a result of the angulation placed on the CR. On PA axial oblique projections, the caudal angle projects the cranial cortex situated farther from the IR approximately 0.25 inch (0.6 cm) inferiorly and the mandibular ramus situated farther from the IR approximately 0.5 inch (1.25 cm) inferiorly. The ramus is projected farther inferiorly because it is located at a larger OID than the cranial cortex. On AP axial oblique projections, the cephalic CR angle projects the cranial cortex and mandibular rami situated farther from the IR superiorly. The distance between these two cortical outlines will be increased or decreased if the head is allowed to tilt toward or away from the IR. Such tilting also causes the upper cervical vertebrae to lean toward or away from the IR. To avoid head and upper cervical column tilting, position the IPL parallel with the floor.

On oblique projections, if the head and upper cervical column are allowed to tilt, the atlas and its posterior arch are distorted. From such a projection, one can determine whether the head and upper cervical vertebrae were tilted toward or away from the IR by evaluating the distance demonstrated between the inferior cranial cortices and the inferior mandibular rami and the openness of the atlas's vertebral foramina. For PA oblique projections, these distances are increased and the foramen is open when the head and upper cervical vertebrae are tilted away from the IR (**Fig. 8.46**). If these distances are decreased and the foramen is not demonstrated, the head and upper cervical vertebrae were tilted toward the IR (**Figs. 8.47** and **8.48**). For AP oblique projections when the head and upper cervical vertebrae are tilted away from the IR, the distances will increase and the foramen is not demonstrated, and when they are tilted toward the IR, the distances will decrease and the foramen is demonstrated.

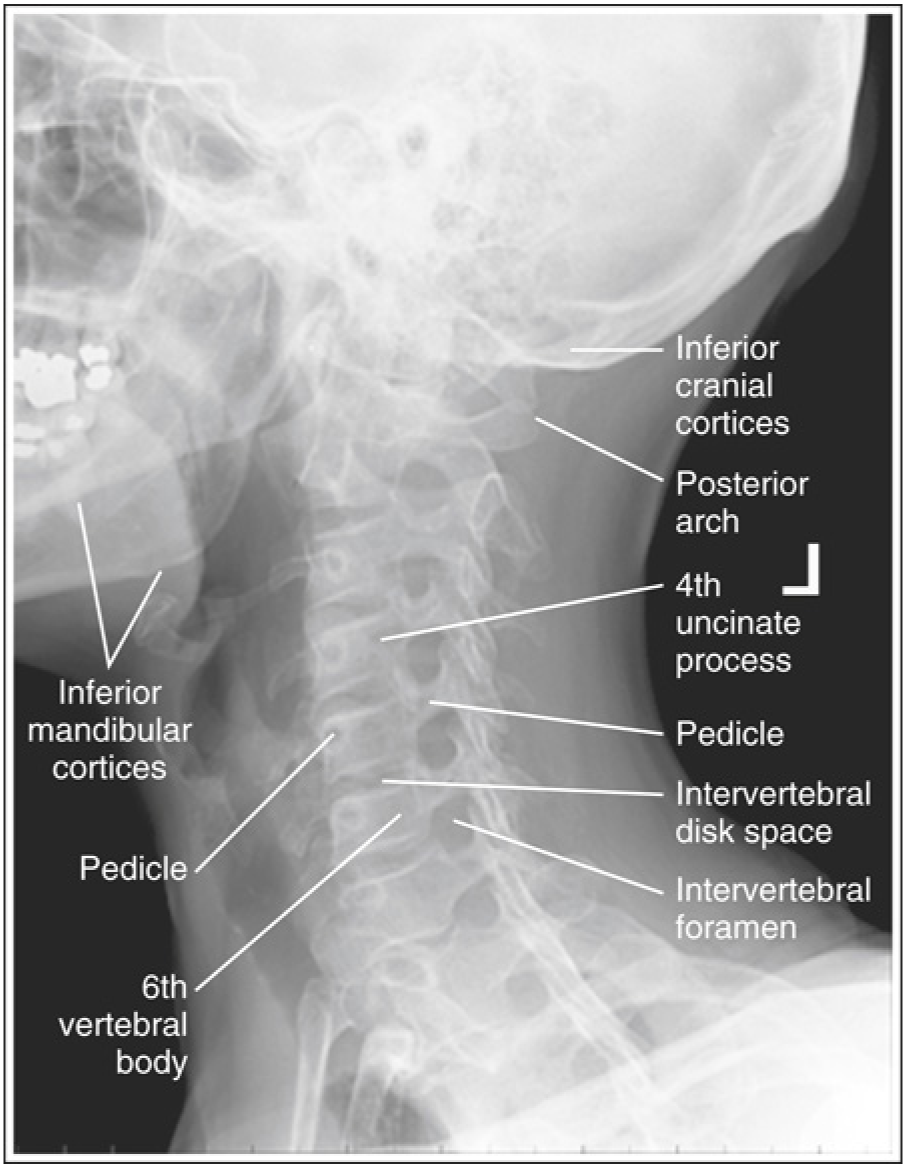


FIGURE 8.39 PA axial oblique cervical vertebrae projection with cranium in lateral projection and accurate positioning.

FIGURE 8.40 PA axial oblique cervical vertebrae projection with cranium in PA oblique projection and accurate positioning.

FIGURE 8.41 Proper patient positioning for PA axial oblique vertebrae cervical projection.

FIGURE 8.42 Proper patient positioning for AP axial oblique vertebrae cervical projection.

TABLE 8.5

AML, Acanthiomeatal line; *AP*, anteroposterior; *CR*, central ray; *EAM*, external auditory meatus; *IPL*, interpupillary line; *IR*, image receptor; *OID*, object–IR distance; *PA*, posteroanterior; *SID*, source–image receptor distance.

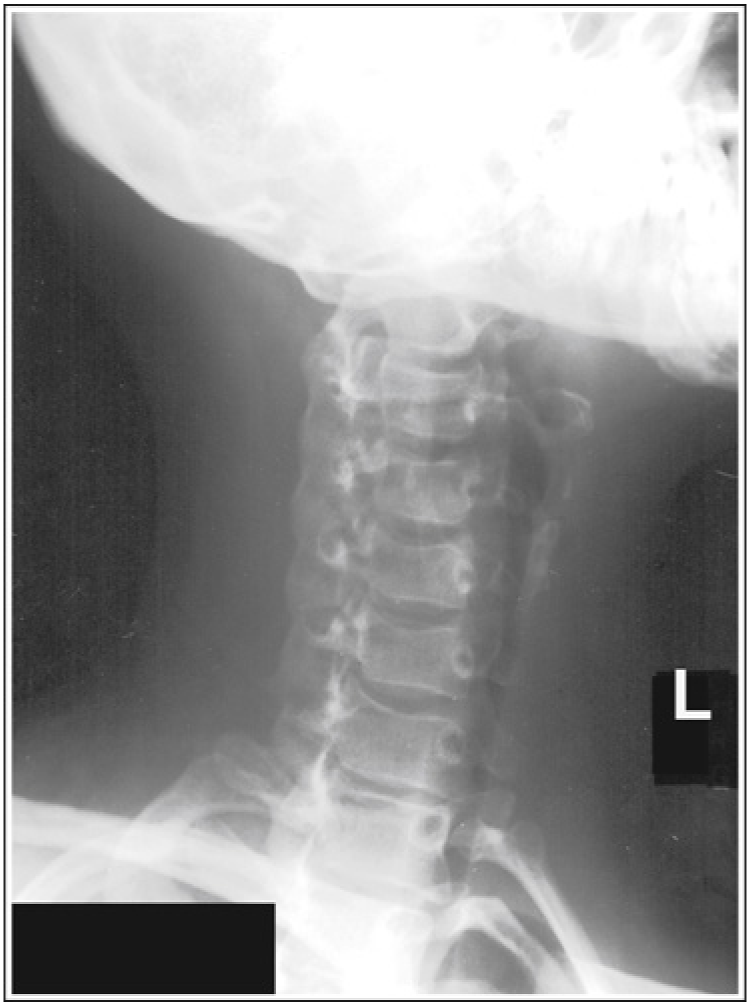


FIGURE 8.43 PA axial oblique cervical vertebrae projection taken with the patient insufficiently rotated.

FIGURE 8.44 PA axial oblique cervical vertebrae projection taken with the patient excessively rotated.

CR Alignment: Intervertebral Disk Space Openness

The cervical vertebral column demonstrates a lordotic curvature. This curvature, along with the shape of the cervical bodies, causes the disk-articulating surfaces of the vertebral bodies to slant downward posteriorly to anteriorly. To obtain open intervertebral disk spaces and undistorted and uniformly shaped vertebral bodies, the upper vertebral column must be aligned parallel with the IR and the CR angled in the same direction as the

slope of the vertebral bodies. This is accomplished by angling the CR 15 to 20 degrees caudally for PA axial oblique projections and 15 to 20 degrees cephalically for AP axial oblique projections.

FIGURE 8.45 PA axial oblique cervical vertebrae projection taken with the upper cervical vertebrae adequately rotated and the lower cervical vertebrae excessively rotated.

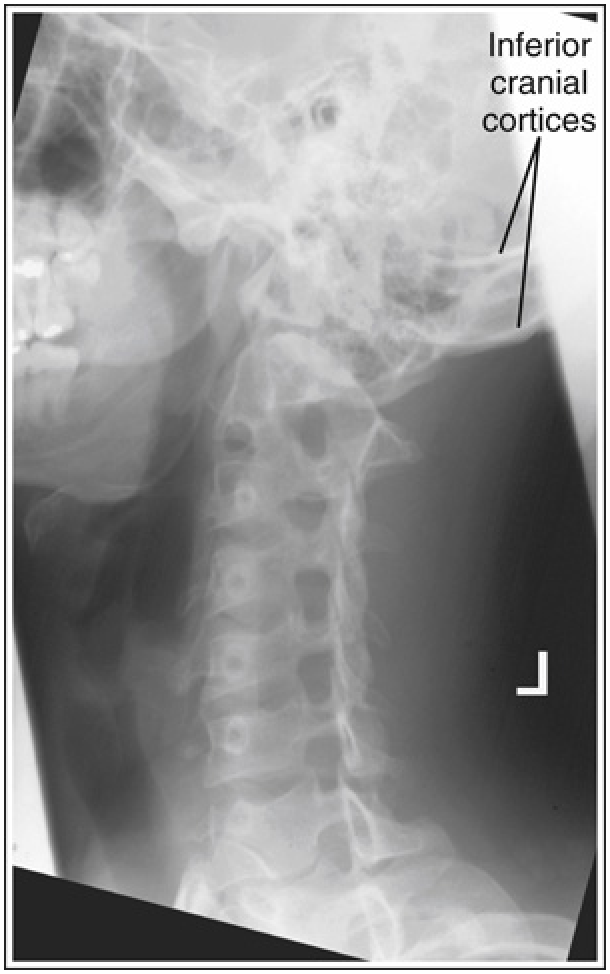


FIGURE 8.46 PA axial oblique cervical vertebrae projection taken with the upper cervical vertebral column and the head tilted away from the IR.

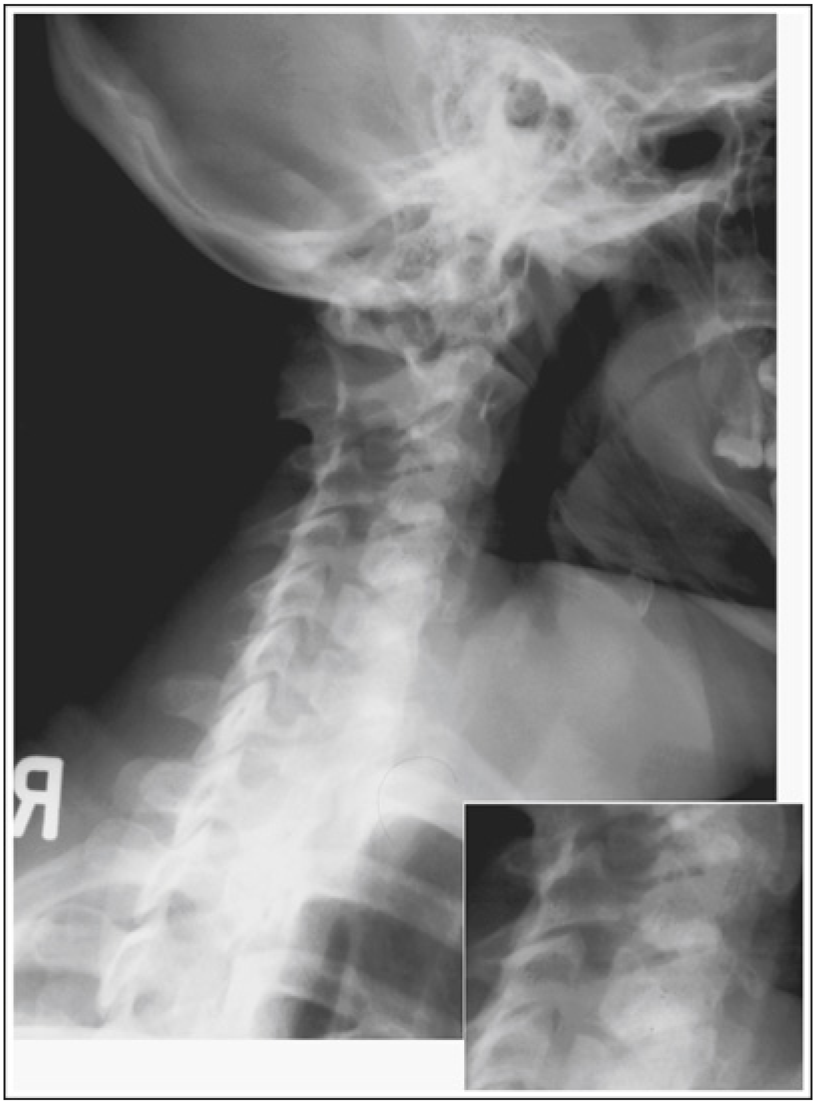


FIGURE 8.47 PA axial oblique cervical vertebrae projection taken with the upper cervical vertebral column and head tilted toward the IR.

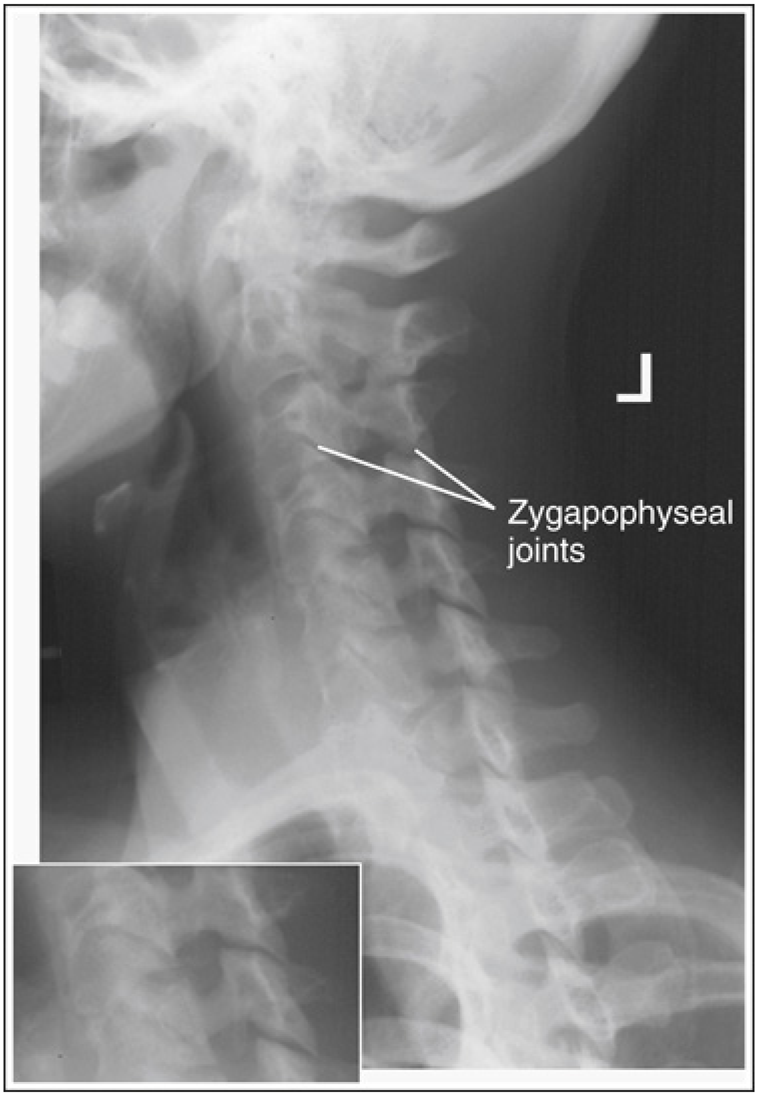


FIGURE 8.48 PA axial oblique cervical vertebrae projection taken with the upper cervical vertebral column tilted toward the IR and the head tilted away from the IR.

If the cervical vertebral column is tilted or if the CR is inaccurately angled with the intervertebral disk spaces, the disk spaces will be obscured and the cervical bodies are not seen as distinct individual structures. The upper and lower cervical vertebrae should be evaluated separately when a poorly positioned axial oblique projection has been obtained, because

cervical vertebral column tilting of the upper cervical vertebrae is caused by the head being positioned too close or far away from the IR (poor IPL positioning) and lower cervical vertebrae tilting is caused by the upper thorax being tilted anteriorly. In addition, because this examination can be performed using anterior or posterior oblique positions that require differing CR angulations, and the typical cervical vertebral series requires the radiographer to change angle directions several times, radiographers should be able to identify a projection that was taken with an incorrect CR angle.

The PA axial oblique projections in **Figs. 8.47** and **8.48** were taken with the cervical vertebral column tilted anteriorly (vertebrae leaning toward the IR) or with the CR angled too close to perpendicular (too cephalically) to align with the intervertebral disk spaces. Note that the intervertebral disk spaces are closed, the cervical bodies are distorted, and zygapophyseal joint spaces are demonstrated. **Fig. 8.48** demonstrates more tilting or an increase in cephalic CR angulation than **Fig. 8.47**, as indicated by the transverse process being seen in the intervertebral foramen. If this same analysis was for an AP projection, the cervical vertebral column would have been tilted anteriorly or the CR angulation would have been positioned too caudally.

Kyphotic Patient

In patients with severe kyphosis, the lower cervical vertebrae are angled toward the IR because of the greater lordotic curvature of this area. To demonstrate the lower cervical vertebrae with open intervertebral disk spaces and undistorted cervical bodies on a patient with this condition, the CR will need to be angled more than the suggested 15 to 20 degrees for the oblique projections. The projection in **Fig. 8.49** was taken on a patient with kyphosis without the increase in CR angulation. Note the difference in the intervertebral disk space openness, vertebral body distortion, and the

demonstration of the zygapophyseal joints between the upper and lower cervical regions.

AML Alignment

Adjusting chin elevation until the AML is aligned parallel with the floor positions the mandible anterior to the first through third cervical vertebrae. If the chin is not properly elevated, the mandibular rami are superimposed over C1, C2, and C3 (**Fig. 8.50**).

Positioning for Trauma

When imaging the cervical vertebrae of a trauma patient with suspected subluxation or fracture, obtain the trauma AP axial and lateral projections and have them evaluated before the patient is moved for the AP axial oblique projection. The trauma AP axial oblique projection of the cervical vertebrae is accomplished by elevating the supine patient's head, neck, and thorax enough to place a lengthwise IR beneath the neck. If the right vertebral foramina and pedicles are of interest, the IR should be shifted to the left enough to align the left mastoid tip with the longitudinal axis of the IR and inferior enough to position the right gonion (angle of jaw when head is in neutral position; C3) with the transverse axis of the IR. Angle the CR 45 degrees medially to the right side of the neck and rotate the tube 15 degrees cephalically, and then center the CR halfway between the anterior and posterior surfaces of the neck at the level of the thyroid cartilage (C4) (**Fig. 8.51**). If the left vertebral foramina and pedicles are of interest, shift the IR to the right enough to align the right mastoid tip with the longitudinal axis of the IR and inferior enough to position the left gonion with the transverse axis of the IR. The CR should be angled and centered as described earlier, except that it should be directed to the left side of the neck. A trauma AP axial oblique cervical projection should meet all the

analysis requirements listed for a regular AP axial oblique cervical projection; the cranium will be in an oblique position (**Fig. 8.52**).

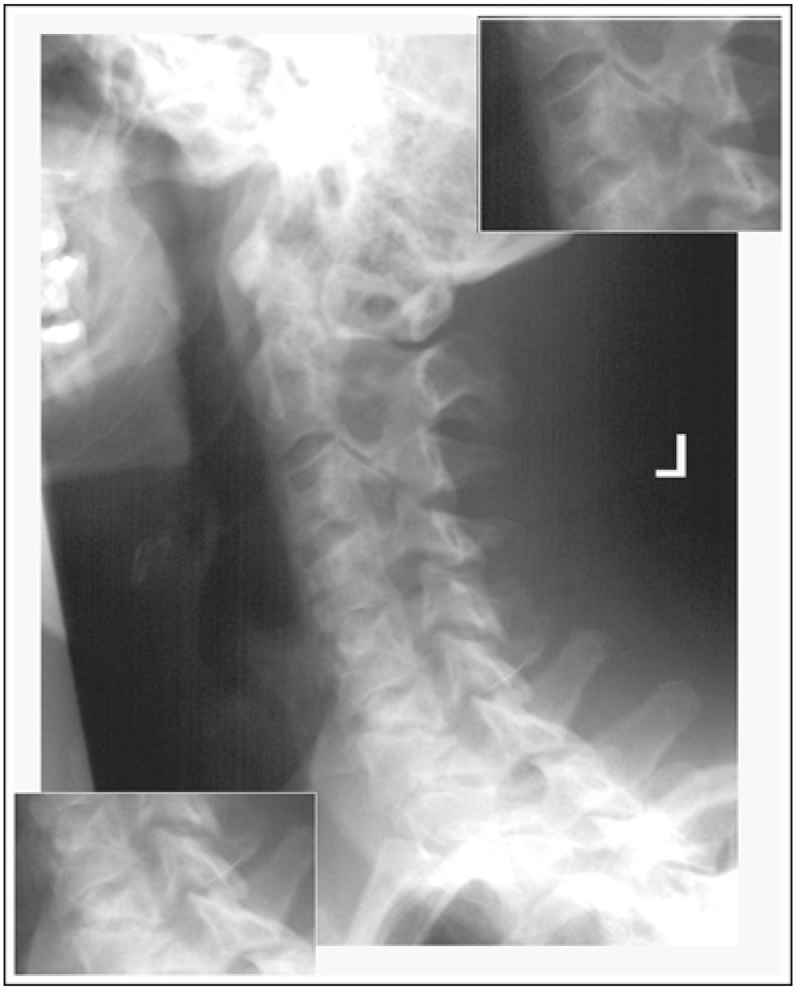


FIGURE 8.49 PA axial oblique cervical vertebrae projection of a patient with kyphosis.

FIGURE 8.50 PA axial oblique cervical vertebrae projection taken with the head in an oblique position and the mandibular rami superimposed over C1, C2, and C3.

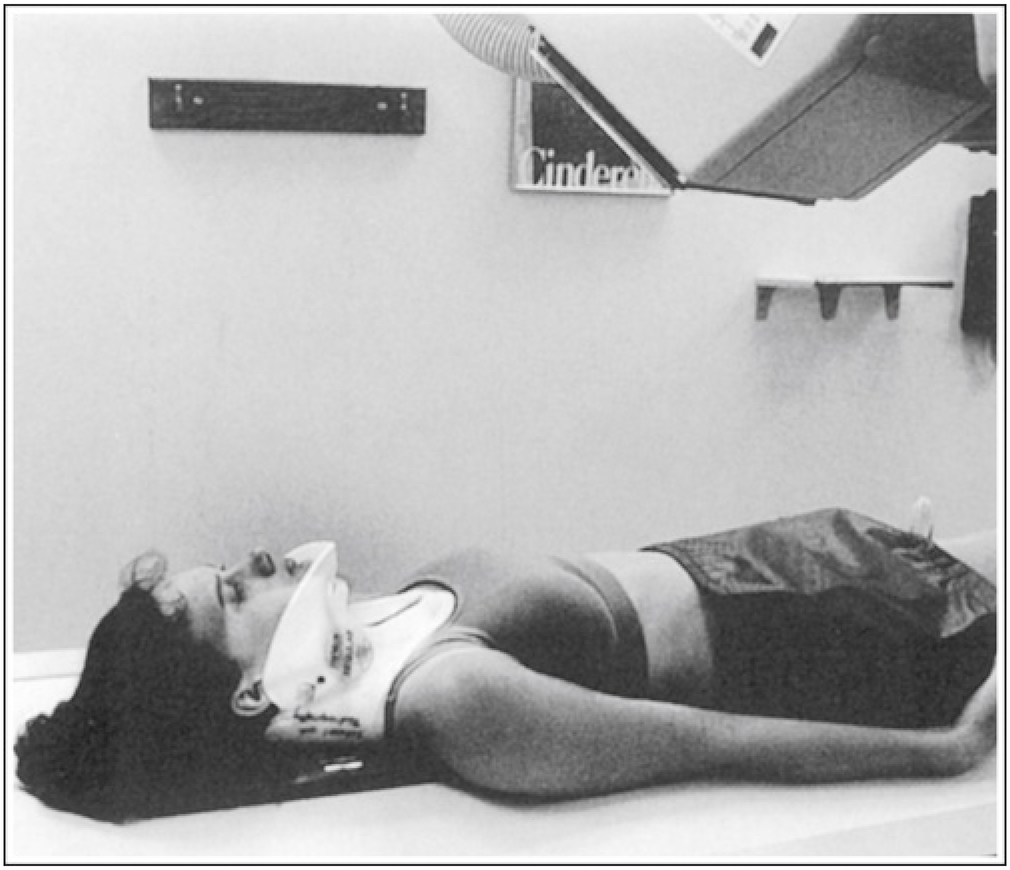


FIGURE 8.51 Proper patient positioning for AP axial oblique cervical vertebrae projection taken to evaluate trauma.

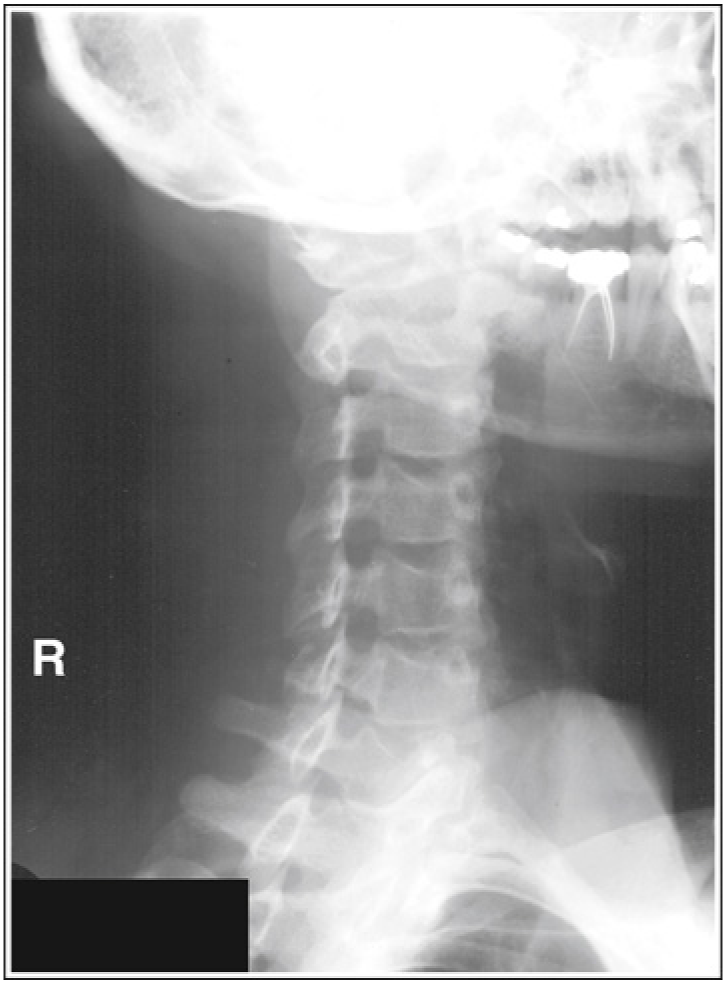


FIGURE 8.52 AP axial oblique cervical vertebrae projection with accurate positioning taken to evaluate trauma.

PA Axial Oblique Cervical Vertebrae Analysis Practice

IMAGE 8.8 PA axial oblique.

Analysis

The pedicles and intervertebral foramina are obscured, and the medial clavicle is superimposed by the vertebral column. The patient was not rotated 45 degrees.

Correction

Increase the patient obliquity until the midcoronal plane is placed at a 45-degree angle with the IR.

IMAGE 8.9 PA axial oblique.

Analysis

The intervertebral disk spaces are closed, the cervical bodies are distorted, and zygapophyseal joint spaces are demonstrated. The cervical vertebral column was tilted anteriorly or the CR angled too close to perpendicular (too cephalically).

Correction

Posteriorly tilt the cervical vertebral column until it is parallel with the IR or adjust the CR angle caudally until it is aligned with the intervertebral disk spaces.

Cervicothoracic Vertebrae: Lateral Projection (Twining Method; Swimmer's Technique)

See **Table 8.6** and **Figs. 8.53** and **8.54**.

Exam Indication

This examination is performed when the routine lateral cervical projection does not adequately demonstrate the seventh cervical vertebra or when the routine lateral thoracic projection does not demonstrate the first through third thoracic vertebrae.

Cervical and Torso Rotation

If the patient is rotated for the cervicothoracic vertebrae projection, the right-side articular pillars, posterior ribs, zygapophyseal joints, and humeri move away from the left side, obscuring the pedicles and distorting the vertebral bodies. When rotation is demonstrated on a lateral projection, determine which side was rotated anteriorly and which side was rotated posteriorly by evaluating the location of the humerus that was positioned closer to the IR, which can be identified by its placement by the head. If this humerus was rotated anteriorly, the shoulder positioned closest to the IR was positioned anteriorly (**Fig. 8.55**). If this humerus was rotated posteriorly, the shoulder positioned closest to the IR was positioned posteriorly (**Fig. 8.56**).

Intervertebral Disk Spaces Openness

To obtain open disk spaces and undistorted vertebral bodies, position the head in a lateral projection, with the IPL perpendicular to and the midsagittal plane parallel with the IR. If the patient is in a recumbent position, it may be necessary to elevate the head on a sponge to place it in a

lateral position and prevent cervical column tilting. If the head and cervical vertebrae are allowed to tilt toward the IR, the intervertebral disk spaces will be closed (**Fig. 8.57**).

TABLE 8.6

ASISs, Anterior superior iliac spines; *CR*, central ray; *IR*, image receptor.

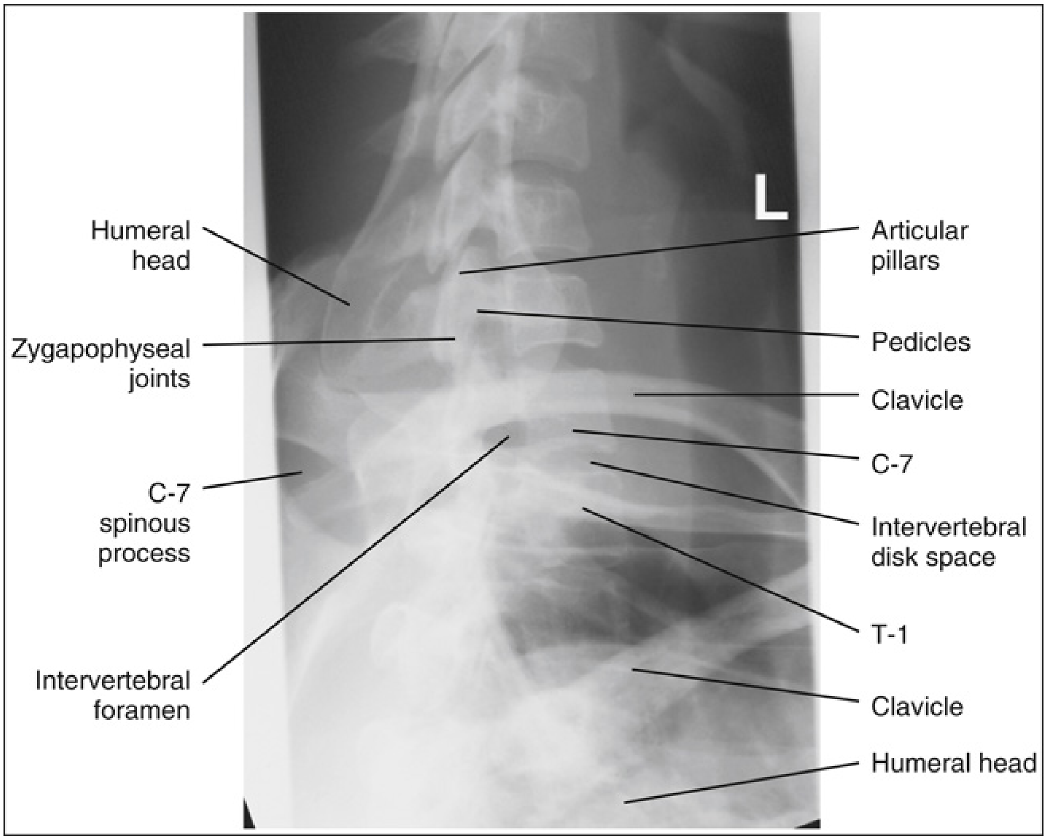


FIGURE 8.53 Lateral cervicothoracic vertebrae projection with accurate positioning.

FIGURE 8.54 Proper patient positioning for recumbent lateral cervicothoracic vertebrae projection.

Positioning for Trauma

When routine cervical projections are obtained in a trauma patient with suspected subluxation or fracture and the seventh lateral cervical vertebra is not demonstrated, obtain the lateral cervicothoracic projection with the

head, neck, and body trunk left as is. Instruct the patient to elevate the arm farther from the x-ray tube and depress the arm closer to the tube. Then place the IR and grid against the lateral body surface, centering its transverse axis at a level 1 inch (2.5 cm) superior to the jugular notch (**Fig. 8.58**). Position the CR horizontal to the posterior neck surface and the center of the IR and grid. If the shoulder closer to the CR is not well depressed, a 5-degree caudal angulation is recommended.

FIGURE 8.55 Lateral cervicothoracic vertebrae projection taken with the left shoulder positioned anteriorly.

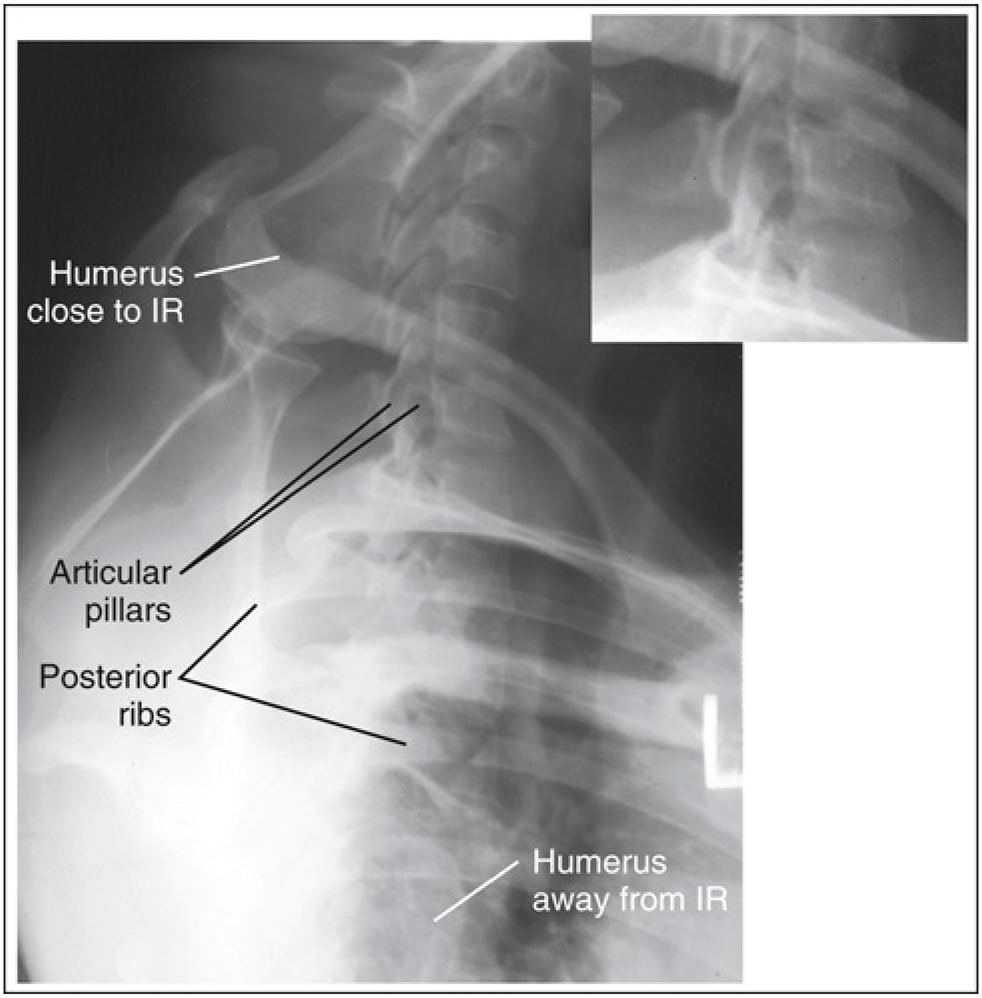


FIGURE 8.56 Lateral cervicothoracic vertebrae projection taken with the left shoulder positioned posteriorly.

FIGURE 8.57 Lateral cervicothoracic vertebrae projection taken with the head and upper cervical vertebrae tilted toward the IR.

Identifying C7

The seventh cervical vertebra can be identified on a lateral cervicothoracic projection by locating the elevated clavicle, which is normally shown traversing the seventh cervical vertebra.

FIGURE 8.58 Proper patient positioning for supine lateral cervicothoracic vertebrae projection.

Lateral Cervicothoracic Vertebrae Analysis Practice

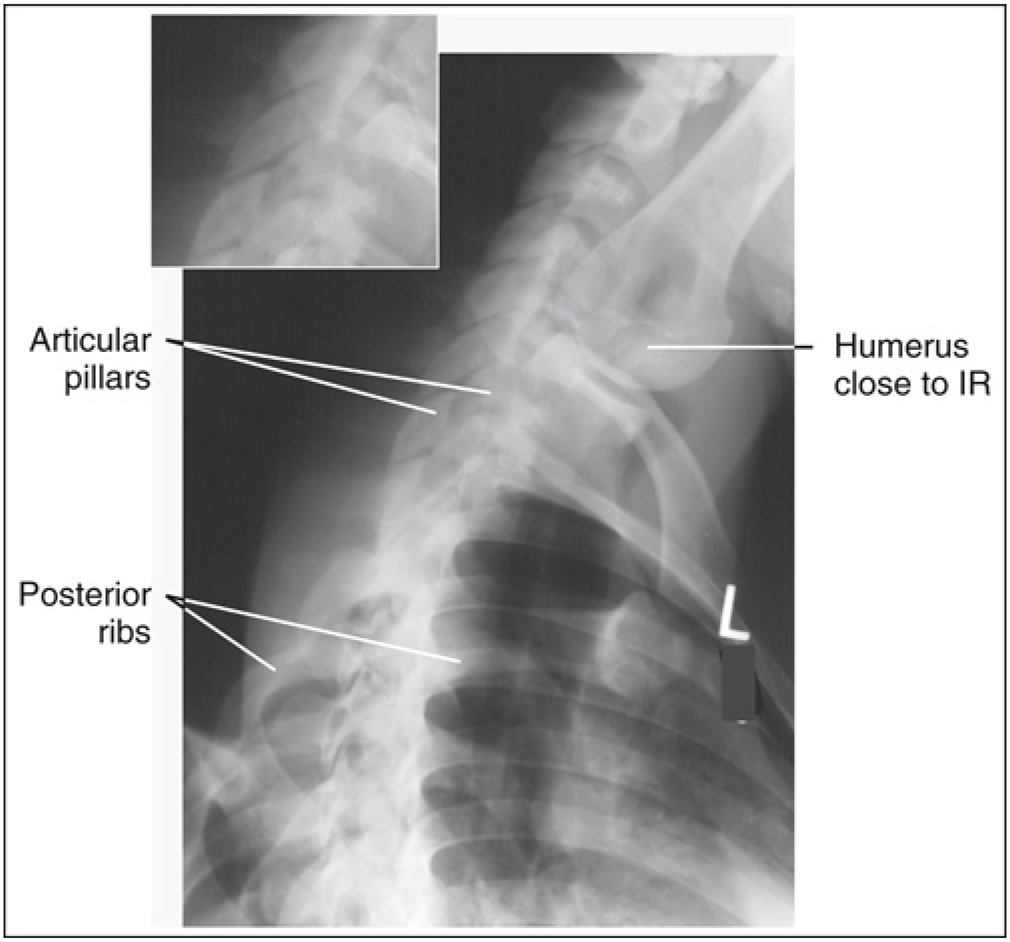


IMAGE 8.10

Analysis

The right and left articular pillars, zygapophyseal joints, and the posterior ribs are demonstrated without superimposition. The left thorax was rotated anteriorly.

Correction

Rotate the right thorax anteriorly until the midcoronal plane is perpendicular to the IR.

Thoracic Vertebrae: AP Projection

See **Table 8.7** and **Figs. 8.59** and **8.60**.

Using Anode Heel Effect

The anode heel effect decreases the number of photons reaching the upper thoracic vertebrae and results in increased brightness in this area. This method works sufficiently in patients who have very little difference in AP body thickness between their upper and lower thoracic vertebrae but does not provide an adequate brightness increase in patients with larger thickness differences. To use the anode heel effect, position the head and upper thoracic vertebrae at the anode end of the tube and the feet and lower thoracic vertebrae at the cathode end. Then set an exposure (milliamperes per second [mAs]) that adequately demonstrates the middle thoracic vertebrae. Because the anode will absorb some of the photons aimed at the anode end of the IR, the upper thoracic vertebrae will receive less exposure than the lower vertebrae.

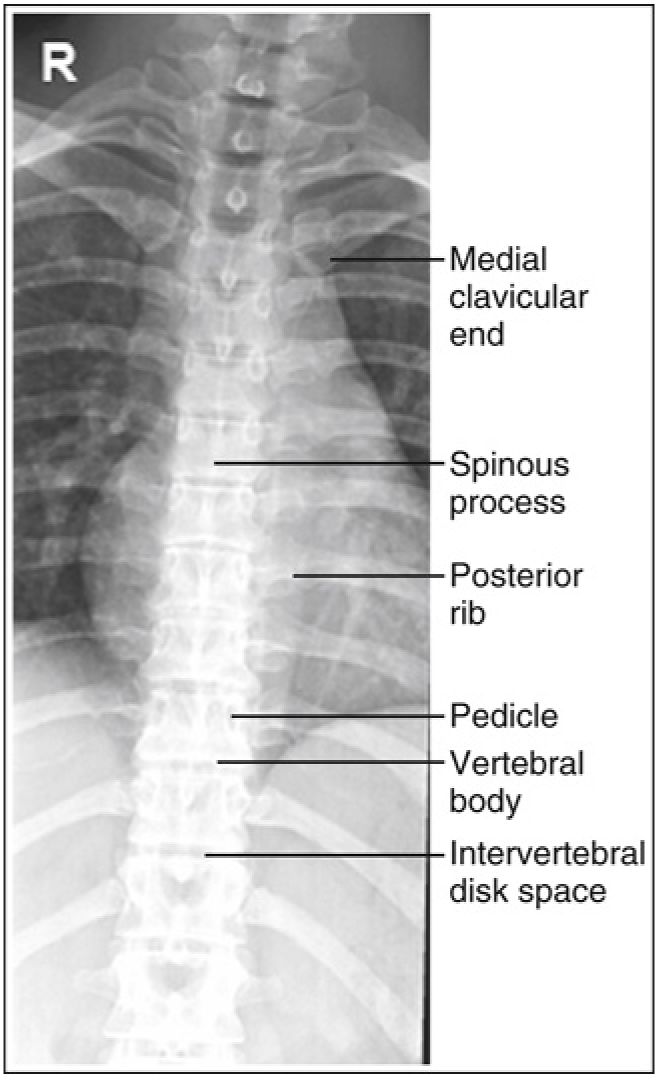


FIGURE 8.59 AP thoracic vertebrae projection with accurate positioning.

TABLE 8.7

AP, Anteroposterior; *ASISs*, anterior superior iliac spines; *CR*, central ray; *IR*, image receptor.

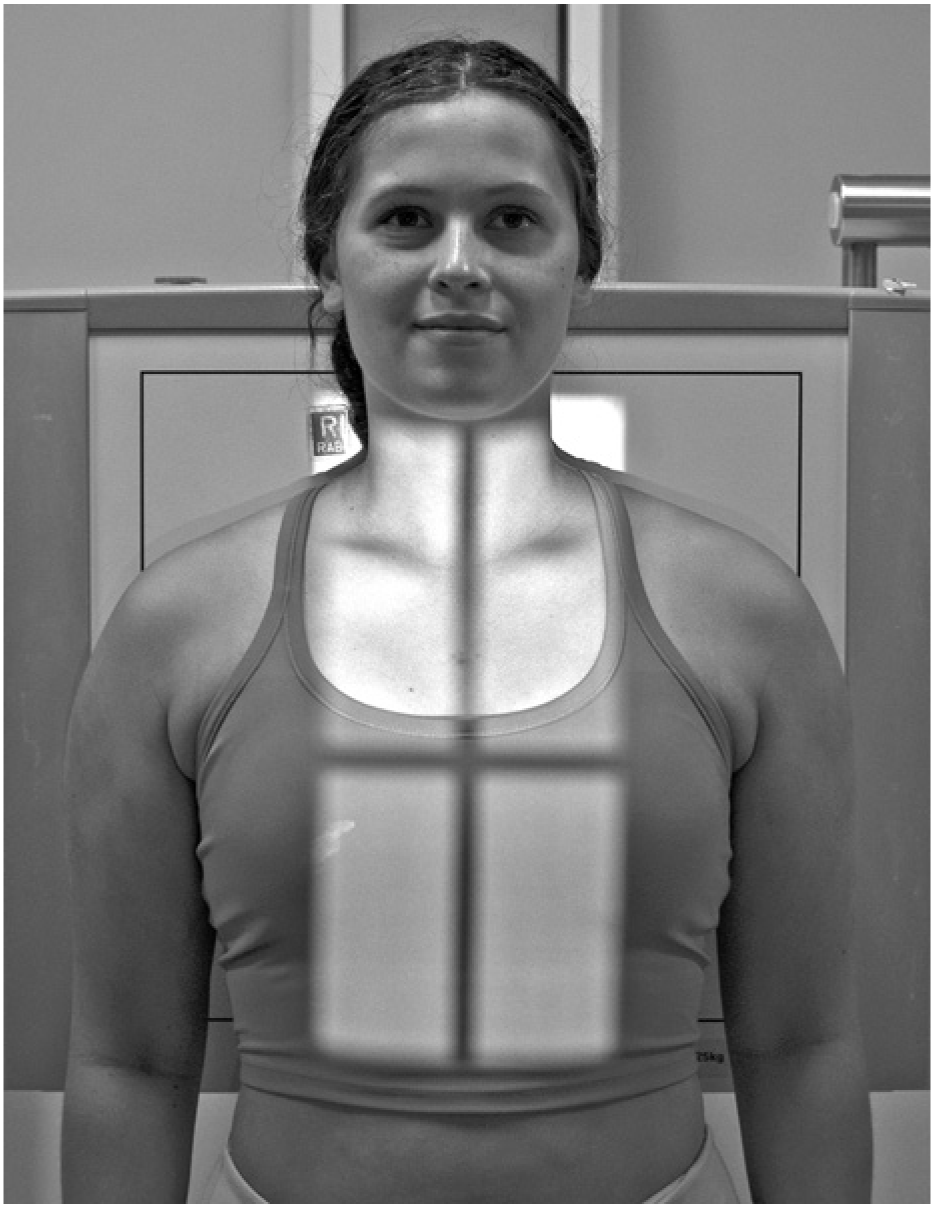


FIGURE 8.60 Proper patient positioning for AP thoracic vertebrae projection.

FIGURE 8.61 AP thoracic vertebrae projection taken with the left side of the upper thorax positioned closer to the IR.

Vertebral Rotation

The upper and lower thoracic vertebrae can demonstrate rotation independently or simultaneously, depending on which section of the body is rotated. If the shoulders and upper thorax were rotated and the pelvis and

lower thorax remained supine, the upper thoracic vertebrae demonstrate rotation. If the pelvis and lower thorax were rotated and the thorax and shoulders remained supine, the lower thoracic vertebrae demonstrate rotation. If the thorax and pelvis were rotated simultaneously, the entire thoracic column demonstrates rotation.

Rotation is effectively detected on an AP thoracic projection by comparing the distances between pedicles and spinous processes on the same vertebra and the distances between the vertebral column and medial ends of the clavicles. When no rotation is present, the comparable distances are equal. If one side demonstrates a larger distance, vertebral rotation is present. The side demonstrating a larger distance is the side of the patient positioned closer to the IR (**Fig. 8.61**).

Scoliotic Patient

In patients with spinal scoliosis, the thoracic bodies may appear rotated because of the lateral twisting of the vertebrae. Scoliosis of the vertebral column can be very severe, demonstrating a large amount of lateral deviation, or it can be subtle, demonstrating only a small amount of deviation (**Fig. 8.62**). Severe scoliosis is very obvious and is seldom mistaken for patient rotation, whereas subtle scoliotic changes may be easily mistaken for rotation. Although both conditions demonstrate unequal distances between the pedicles and spinous processes, certain clues can be used to distinguish subtle scoliosis from rotation. The long axis of a rotated vertebral column remains straight, whereas the scoliotic vertebral column demonstrates lateral deviation. When the thoracic vertebrae demonstrate rotation, it has been caused by the rotation of the upper or lower torso. Rotation of the middle thoracolumbar vertebrae does not occur unless the upper and lower thoracic vertebrae also demonstrate rotation. On an AP

projection of a patient with scoliosis, the thoracolumbar vertebrae may demonstrate rotation without corresponding upper or lower vertebral rotation.

Intervertebral Disk Space Openness

To obtain open intervertebral disk spaces, the CR must be aligned parallel with the spaces. The thoracic vertebral column demonstrates a kyphotic curvature that somewhat naturally aligns with the diverged x-ray beams. Because the thoracic vertebrae have very limited flexion and extension movements, it is difficult to achieve a significant reduction of this curvature when a patient has increased kyphosis. A small reduction can be obtained on the supine patient by placing the head on a thin pillow or sponge and flexing the hips and knees until the lower back rests firmly against the imaging table. Both procedures improve the relationship of the upper and lower vertebral disk spaces and bodies with the x-ray beam. The head position reduces the upper vertebral curvature, and the hip and knee position reduces the lower vertebral curvature. If the intervertebral disk spaces are not demonstrated as open spaces, it is difficult for the reviewer to evaluate the height of the disk spaces and vertebral bodies (**Fig. 8.63**).

Kyphotic Patient

To demonstrate open disk spaces and undistorted vertebral bodies in a patient with excessive spinal kyphosis, it may be necessary to angle the CR until it is perpendicular to the vertebral area of interest, which may vary between the upper and lower thoracic regions. Because it is painful for such a patient to lie supine on the imaging table, it is best to perform the examination with the patient upright, or in a lateral recumbent position with use of a horizontal beam.

Expiration Versus Inspiration

Patient respiration determines the amount of brightness and contrast resolution demonstrated between the mediastinum and vertebral column. These differences are a result of the variation in atomic density that exists between the thoracic cavity and the vertebrae. The thoracic cavity is largely composed of air, which contains very few atoms in a given area; the same area of bone, as in the vertebrae, contains many compacted atoms. As radiation goes through the body, fewer photons are absorbed in the thoracic cavity than in the vertebral column because fewer atoms with which the photons can interact are present in the thoracic cavity. Consequently, more photons will penetrate the thoracic cavity to expose the IR than will penetrate the vertebral column. Taking the exposure on full suspended expiration reduces the air volume and compresses the tissue in this area, allowing better visualization of the posterior ribs and mediastinum region (compare **Figs. 8.59** and **8.64**). However, it should be noted that the contrast created on an AP thoracic vertebral projection taken on inspiration can be valuable in detecting thoracic tumors or disease.

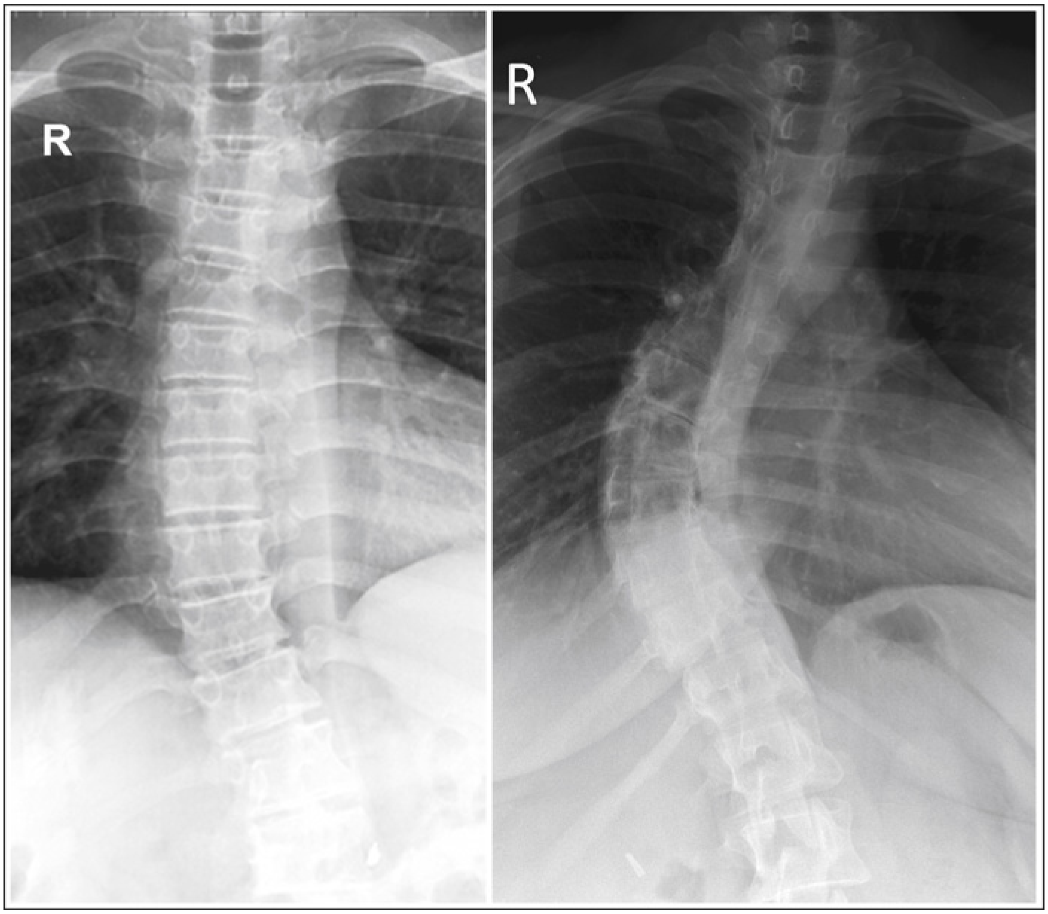


FIGURE 8.62 AP thoracic vertebrae projection demonstrating spinal scoliosis.

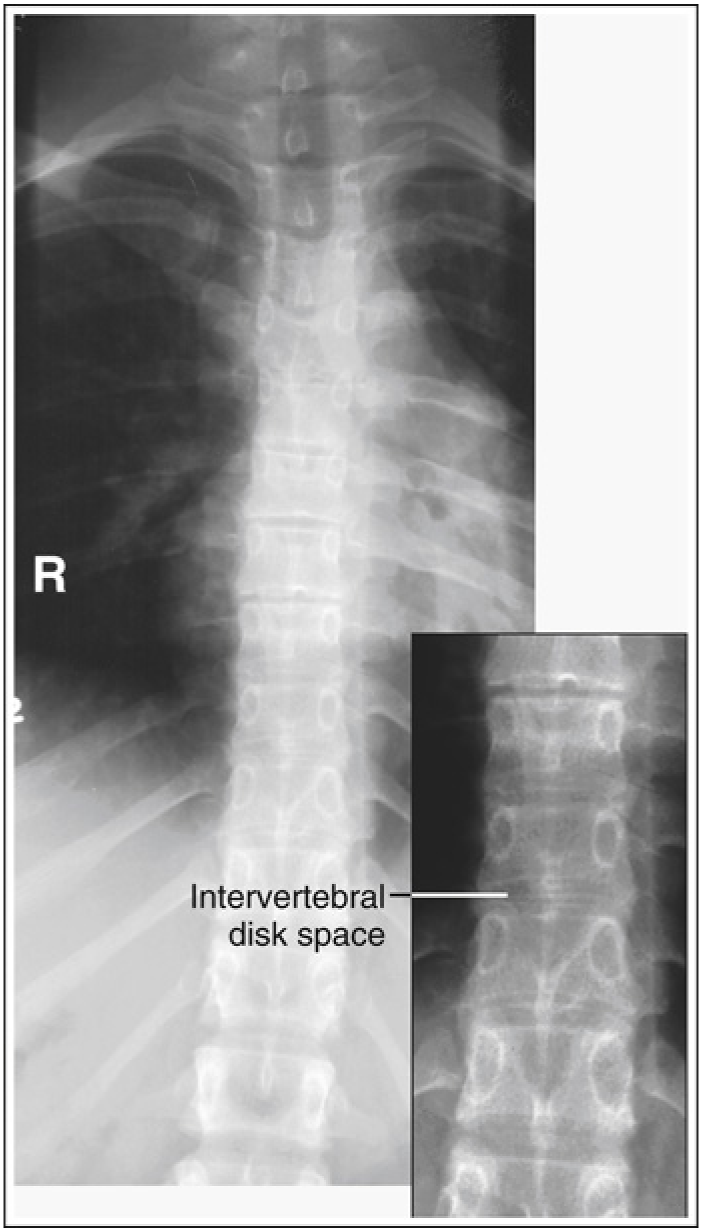


FIGURE 8.63 AP thoracic vertebrae projection taken with the legs extended.

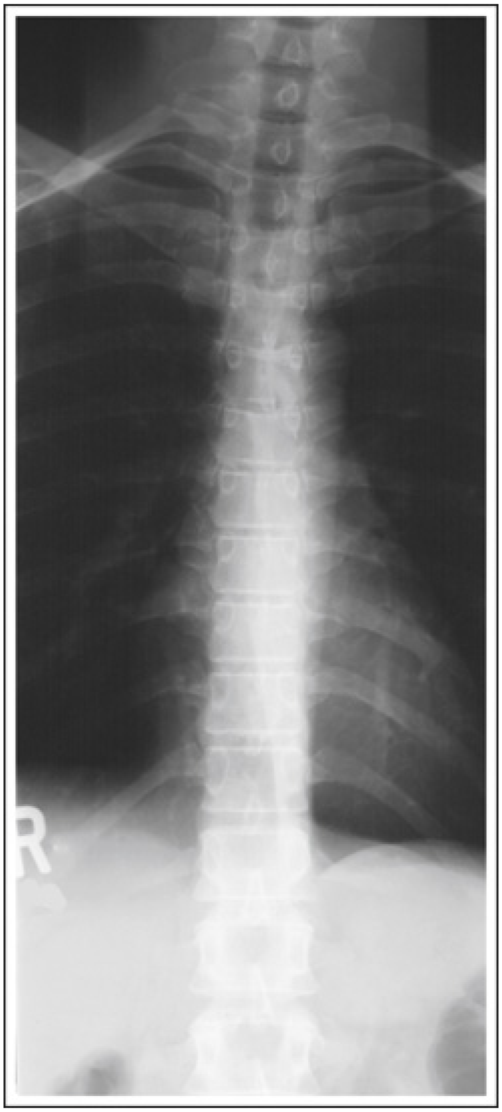


FIGURE 8.64 AP thoracic vertebrae projection taken after full inspiration.

AP Thoracic Vertebrae Analysis Practice

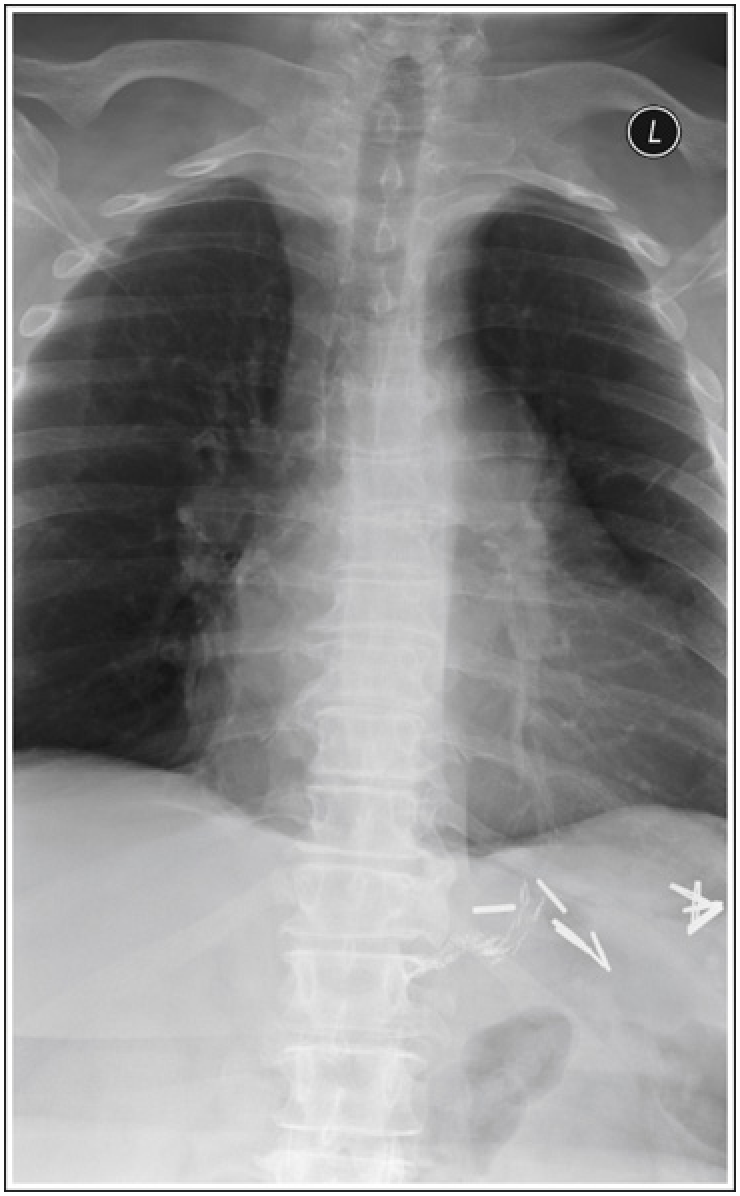


IMAGE 8.11

Analysis

The upper thoracic intervertebral disk spaces are closed, and the CR was centered too inferiorly. The CR and upper thoracic disk spaces were not parallel.

Correction

Center the CR halfway between the jugular notch and xiphoid.

Thoracic Vertebrae: Lateral Projection

See **Table 8.8** and **Figs. 8.65** and **8.66**.

Vertebral Rotation

The upper and lower thoracic vertebrae can demonstrate rotation independently or simultaneously, depending on which section of the torso was rotated. If the shoulders were not placed on top of each other but the anterior superior iliac spines (ASISs) were aligned, the upper thoracic vertebrae demonstrate rotation and the lower thoracic vertebrae demonstrate a lateral projection. If the ASISs were rotated but the shoulders were placed on top of each other, the lower thoracic vertebrae demonstrate rotation and the upper vertebrae demonstrate a lateral projection.

Rotation can be detected on a lateral thoracic projection by evaluating the superimposition of the right and left posterior surfaces of the vertebral bodies and the amount of posterior rib superimposition. On a nonrotated lateral projection, the posterior surfaces are superimposed and the posterior ribs are almost superimposed. Because the posterior ribs positioned farther from the IR were placed at a greater OID than the other side, they demonstrate more magnification. This magnification prevents the posterior ribs from being directly superimposed but positions them approximately 1 inch (2.5 cm) apart. This distance is based on a 40-inch (102-cm) source–IR distance (SID). If a longer SID is used, the distance between the posterior ribs is decreased, and if a shorter SID is used, the distance is increased. On rotation, the right and left posterior surfaces of the vertebral bodies are demonstrated one anterior to the other on a lateral projection. Because the two sides of the thorax and vertebrae are mirror images, it is very difficult

to determine from a rotated lateral projection which side of the patient was rotated anteriorly and which posteriorly. If the patient was only slightly rotated, one way of determining which way the patient was rotated is to evaluate the amount of posterior rib superimposition. If the elevated side was rotated posteriorly, the posterior ribs demonstrate more than 1 inch (2.5 cm) of space between them (**Figs. 8.67** and **8.68**). If the elevated side was rotated anteriorly, the posterior ribs are superimposed on slight rotation (**Fig. 8.69**) and demonstrate greater separation as rotation of the patient increases. Another method is to view the scapulae and humeral heads when visible. The scapula and humeral head demonstrating the greatest magnification will be the ones situated farthest from the IR (see **Fig. 8.68**).

TABLE 8.8

ASISs, Anterior superior iliac spines; *CR*, central ray; *IR*, image receptor.

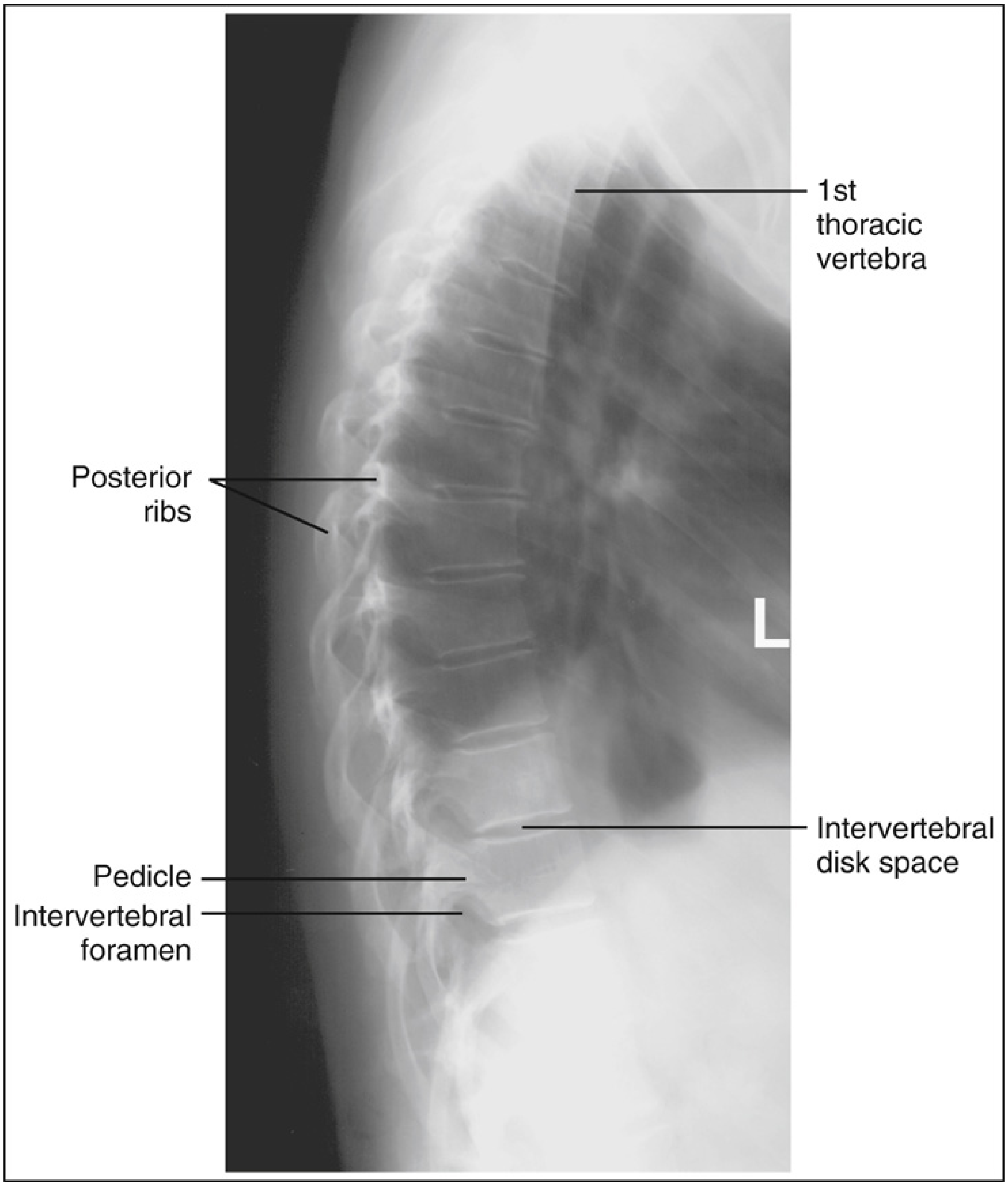


FIGURE 8.65 Lateral thoracic vertebrae projection with accurate positioning.

FIGURE 8.66 Proper patient positioning for lateral thoracic vertebrae projection.

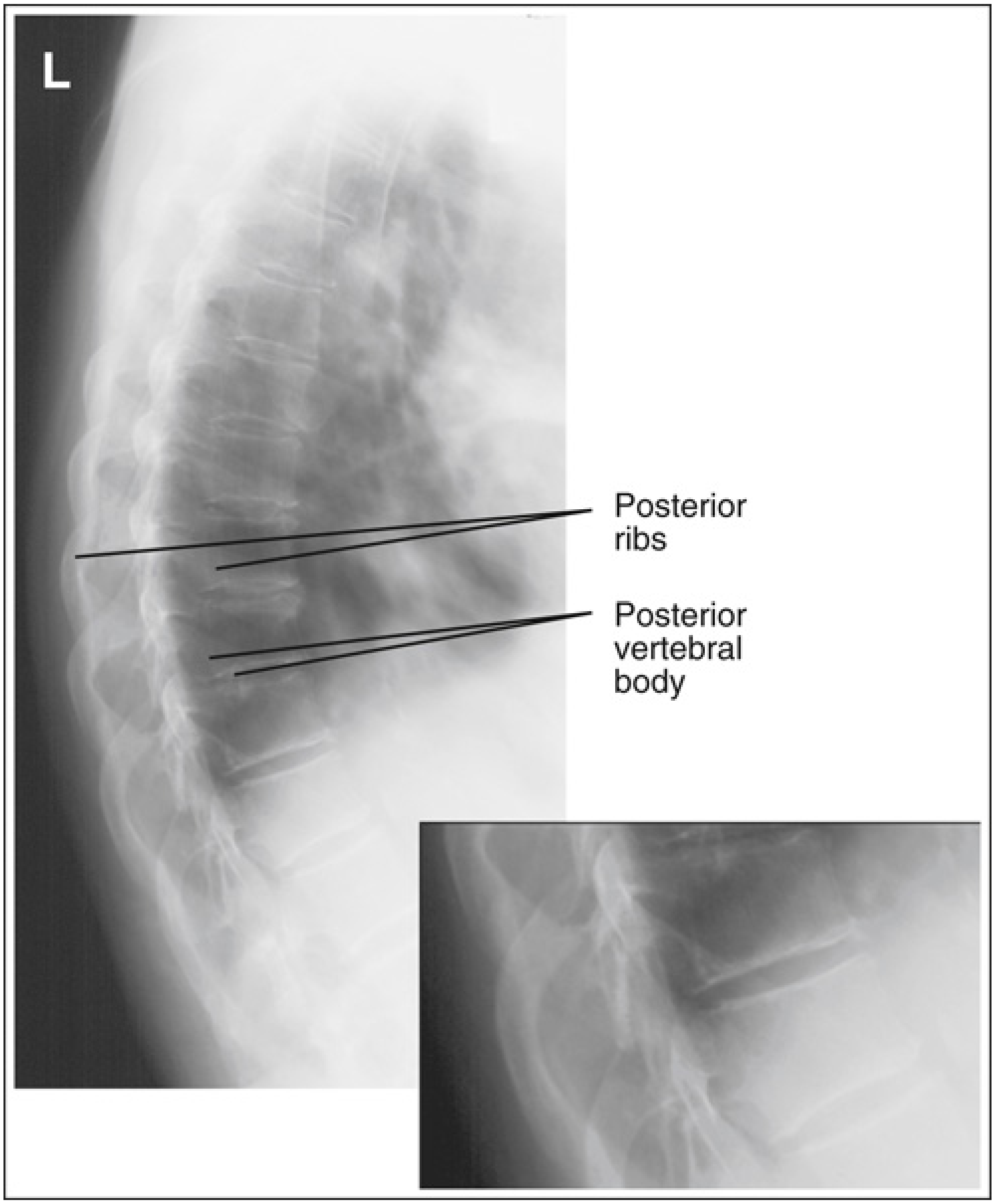


FIGURE 8.67 Lateral thoracic vertebrae projection taken with the right side rotated posteriorly.

Rotation Versus Scoliosis

On the lateral projection of a patient with spinal scoliosis, the lung field may appear rotated because of the lateral deviation of the vertebral column (**Fig. 8.70**). On such a projection, the posterior ribs demonstrate differing

degrees of separation depending on the severity of the scoliosis. View the accompanying AP thoracic projection (see **Fig. 8.63**) to confirm this patient condition.

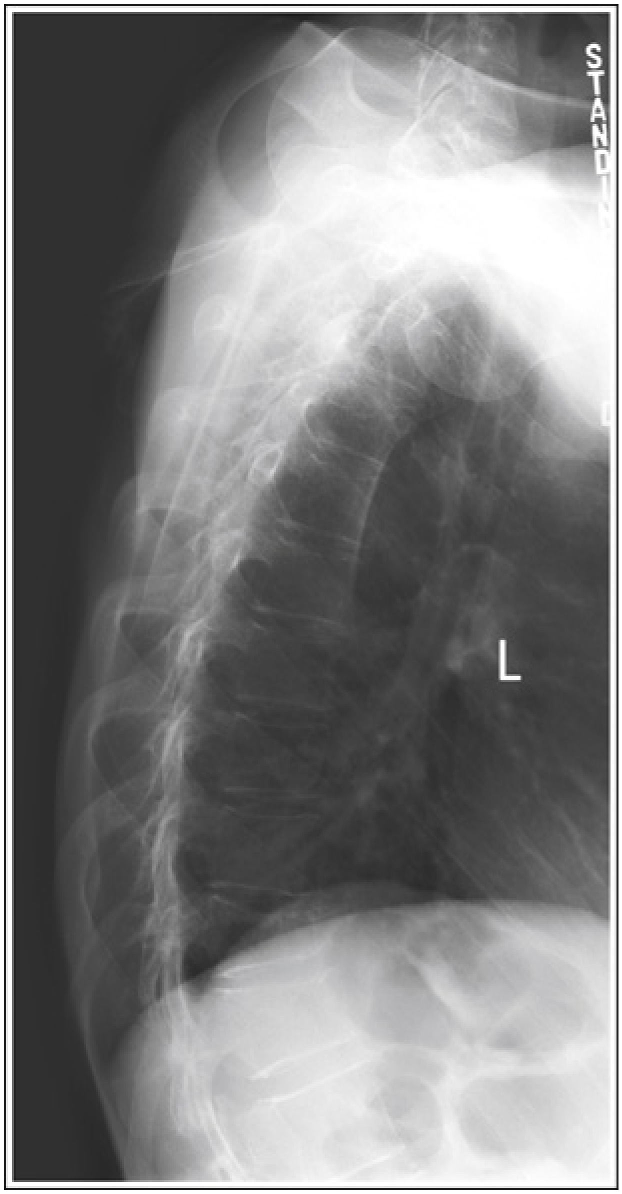


FIGURE 8.68 Lateral thoracic vertebrae projection taken with the right side rotated posteriorly.

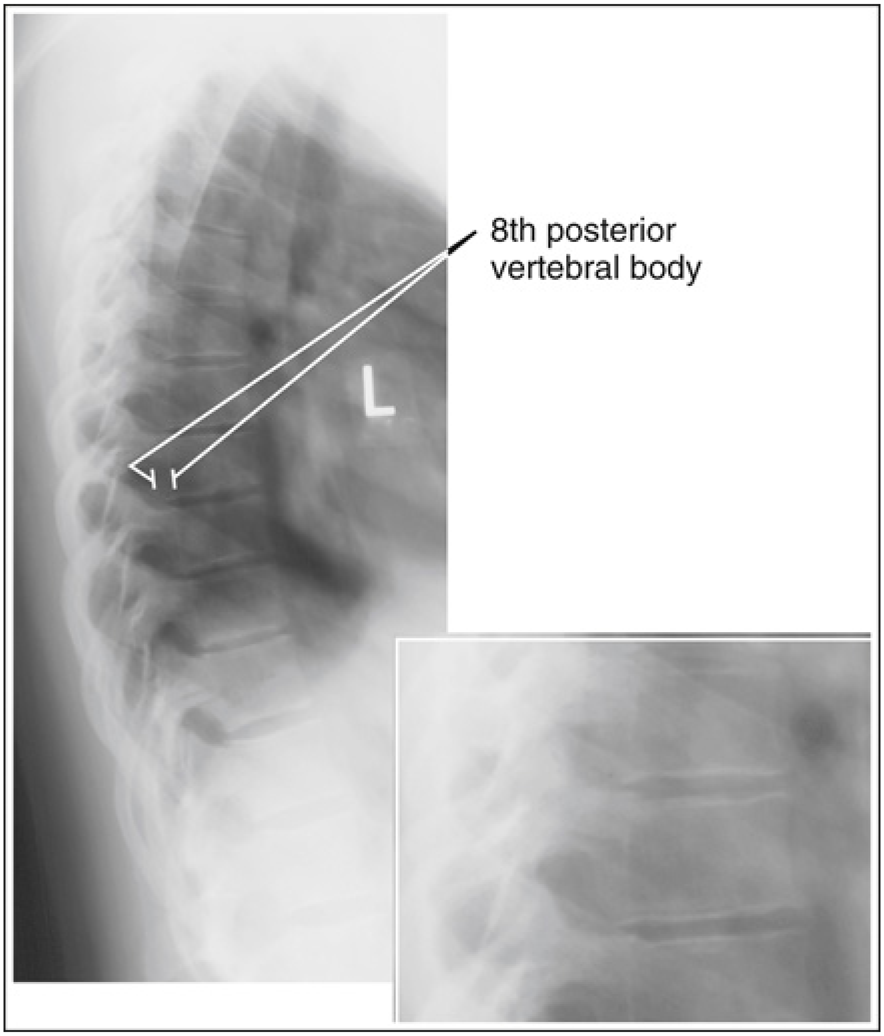


FIGURE 8.69 Lateral thoracic vertebrae projection taken with the right side rotated anteriorly.

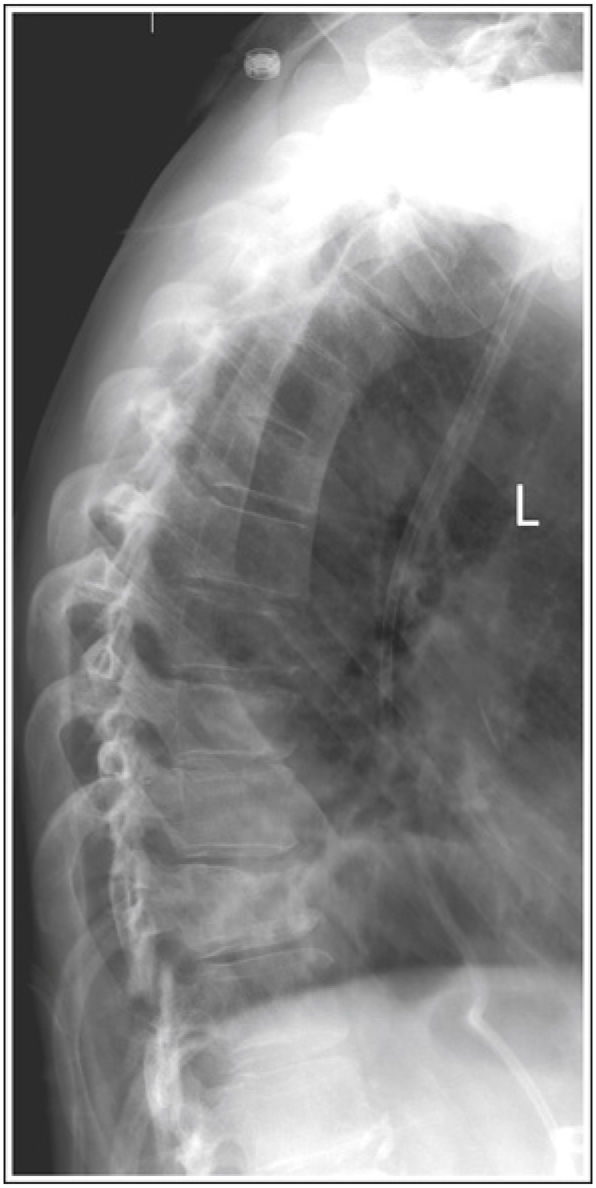


FIGURE 8.70 Lateral thoracic vertebrae projection of a patient with spinal scoliosis.

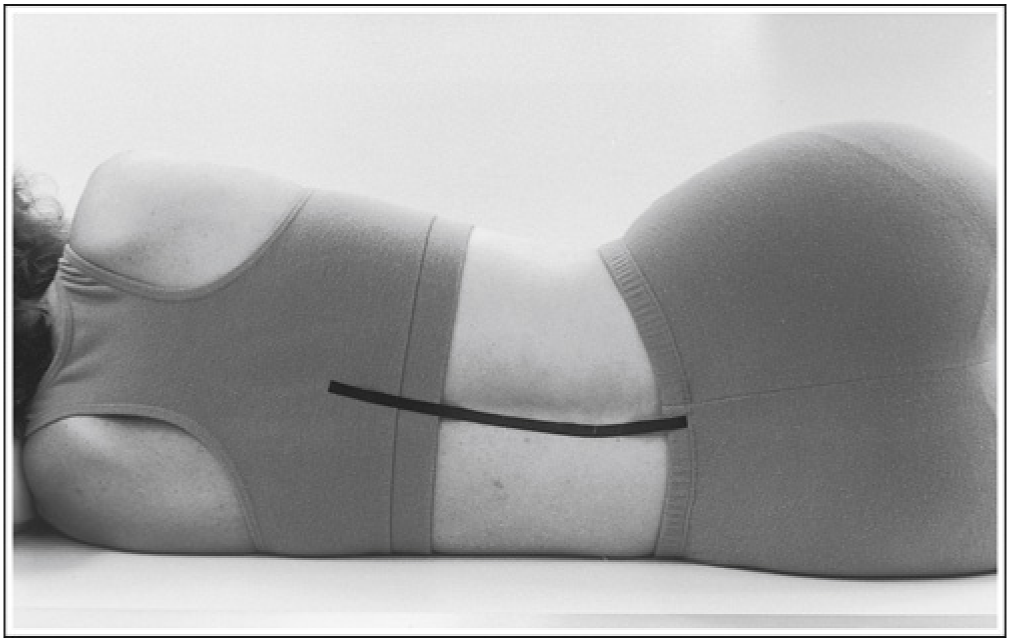


FIGURE 8.71 Poor alignment of vertebrae vertebral column with imaging table.

CR Intervertebral Disk Space Alignment

The thoracic and lumbar vertebral columns are capable of lateral flexion. When the patient is placed in a lateral recumbent position, the vertebral column may not be aligned parallel with the imaging table and IR but may sag at the level of the lower thoracic and lumbar vertebrae region, especially in a patient who has broad shoulders and narrow hips or wide hips and a narrow waist (**Fig. 8.71**). This sagging results in the thoracic column being tilted with the IR. If the thoracic column is allowed to tilt with the IR, the x-ray beams will not be aligned parallel with the intervertebral disk spaces and perpendicular with the vertebral bodies. Tilting on a lateral thoracic projection is most evident at the lower thoracic vertebral region, where it causes the intervertebral disk spaces to be closed and the vertebral bodies to be distorted (see **Figs. 8.67** and **8.72**). For a patient who has a tilted thoracic column, it may be necessary to tuck an

immobilization device between the lateral body surface and imaging table just superior to the iliac crest, elevating the sagging area. The radiolucent sponge should be thick enough to bring the thoracic vertebral column parallel with the imaging table and IR.

An alternative method of obtaining open intervertebral disk spaces and undistorted thoracic bodies in a patient whose thoracic column is tilted with the IR is to angle the CR until it is aligned perpendicular with the vertebral column.

Locating T7 and T12

With the arm positioned at a 90-degree angle with the body, the inferior scapular angle is placed over the seventh thoracic vertebrae.

When viewing a lateral thoracic projection, you can be sure that the twelfth thoracic vertebra has been included by locating the vertebra that has the last rib attached to it. This is the twelfth vertebra. To confirm this finding, follow the posterior vertebral bodies of the lower thoracic and upper lumbar vertebrae, watching for the subtle change in curvature from kyphotic to lordotic. The twelfth thoracic vertebra is located just above it. The first thoracic vertebra can be identified on a lateral thoracic projection by counting up from the twelfth thoracic vertebra or by locating the seventh cervical vertebral prominens. The first thoracic vertebra is at the same level as this prominens.

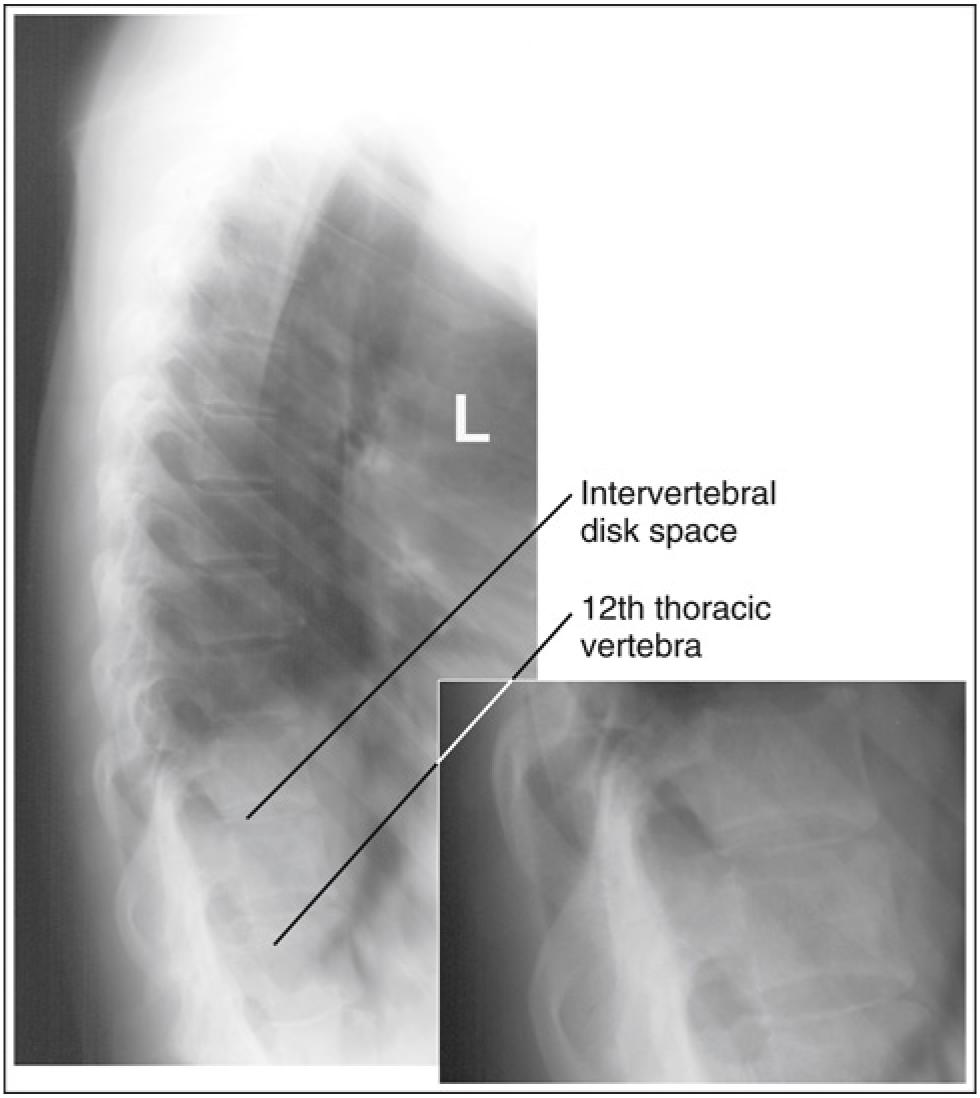


FIGURE 8.72 Lateral thoracic vertebrae projection taken with the lower thoracic vertebrae positioned closer to the IR than the upper thoracic vertebrae.

Lateral Cervicothoracic (Twining Method) Projection

Because of shoulder thickness and the superimposition of the shoulders over the first through third thoracic vertebrae, it may be necessary to take a supplementary projection of this area to demonstrate the thoracic vertebrae. Refer to the description of this projection presented earlier in this chapter.

Breathing Technique

The thoracic vertebrae have many overlying structures, including the axillary ribs and lungs. Using a long exposure time (3 to 4 seconds) and requiring the patient to breathe shallowly (costal breathing) during the exposure forces a slow and steady, upward and outward movement of the ribs and lungs. This technique is often referred to as breathing technique. This movement causes blurring of the ribs and lung markings on the projection, providing greater thoracic vertebral demonstration (see **Fig. 8.65**). Deep breathing, which requires movement (elevation) of the sternum and a faster and expanded upward and outward movement of the ribs and lungs, should be avoided during the breathing technique because deep breathing results in motion of the thoracic cavity and vertebrae (**Fig. 8.73**). If patient motion cannot be avoided when using the extended 3 to 4 seconds for breathing technique, take the projection on suspended expiration to reduce the air volume within the thoracic cavity (**Fig. 8.74**).

FIGURE 8.73 Lateral thoracic vertebrae projection taken with patient breathing deeply and with the lower thoracic vertebrae positioned closer to the IR than the upper thoracic vertebrae.

FIGURE 8.74 Lateral thoracic vertebrae projection taken with suspended respiration.

Lateral Thoracic Vertebrae Analysis Practice

IMAGE 8.12

Analysis

The posterior ribs demonstrate more than 0.5 inch (1.25 cm) of space between them. The right thorax was rotated posteriorly.

Correction

Rotate the right thorax anteriorly until the midcoronal plane is perpendicular with the IR.

Chapter 9: Image Analysis of the Lumbar Vertebrae, Sacrum, and Coccyx

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Identify the required anatomy on lumbar, sacral, and coccygeal projections.
- Describe how to position the patient, image receptor (IR), and central ray (CR) properly for lumbar, sacral, and coccygeal projections.
- State how to mark and display lumbar, sacral, and coccygeal projections properly.
- List the typical artifacts that are found on lumbar, sacral, and coccygeal projections.

- List the image analysis guidelines for lumbar, sacral, and coccygeal projections with accurate positioning.
- State how to reposition the patient properly when lumbar, sacral, and coccygeal projections with poor positioning are produced.
- Discuss how to determine the amount of patient or CR adjustment required to improve lumbar, sacral, and coccygeal projections with poor positioning.
- State the curvature of the lumbar vertebrae, sacrum, and coccyx.
- State which zygapophyseal joints are demonstrated when posterior and anterior oblique lumbar projections are produced.
- List the anatomic structures that make up the parts of the “Scottie dogs” demonstrated on an oblique lumbar image with accurate positioning.
- Explain which procedures are used to produce lateral lumbar, L5-S1 spot, sacral, and coccygeal projections with the least amount of scatter radiation reaching the IR.
- State two methods of positioning the long axis of the lumbar column parallel with the IR for a lateral lumbar projection.
- Describe how the patient is positioned to demonstrate anteroposterior (AP) mobility of the lumbar vertebral column.
- State why the patient is instructed to empty the bladder and colon before an AP sacral or coccygeal projection is taken.

KEY TERM

interiliac line

Image Analysis Guidelines

Technical Data

See **Table 9.1** and **Box 9.1**.

Lumbar Vertebrae: AP Projection

See **Table 9.2** and **Figs. 9.1** and **9.2**.

Psoas Muscle Demonstration

The soft tissue structures that are visualized on anteroposterior (AP) lumbar vertebral projections are the psoas muscles. They are located laterally to the lumbar vertebrae, originating at the first lumbar vertebra on each side and extending to the corresponding side's lesser trochanter. They are used in lateral flexion and rotation of the thigh and in flexion of the vertebral column. On an AP lumbar projection, they are visible on each side of the vertebral bodies as long, triangular soft tissue shadows when appropriate exposure and positioning has been accomplished.

Rotation

The upper and lower lumbar vertebrae can demonstrate rotation independently or simultaneously, depending on which section of the body is rotated. If the thorax was rotated and the pelvis remained supine, the upper lumbar vertebrae demonstrate rotation. If the pelvis was rotated and the thorax remained supine, the lower lumbar vertebrae demonstrate rotation. If the thorax and pelvis were rotated simultaneously, the entire lumbar column demonstrates rotation.

Box 9.1 Lumbar Vertebrae, Sacrum, and Coccyx

Guidelines

VOI, Values of interest.

- The facility's identification requirements are visible.
- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomic structures are sharply defined.
- Contrast resolution is adequate to demonstrate the soft tissue, bony trabecular patterns, and cortical outlines.
- No quantum mottle or saturation is present.
- Scatter radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

TABLE 9.1

AEC, Automatic exposure control; *AP*, anteroposterior; *SID*, source–image receptor distance.

* Use grid if part thickness measures 4 inches (10 cm) or more and adjust mAs per grid ratio requirement.

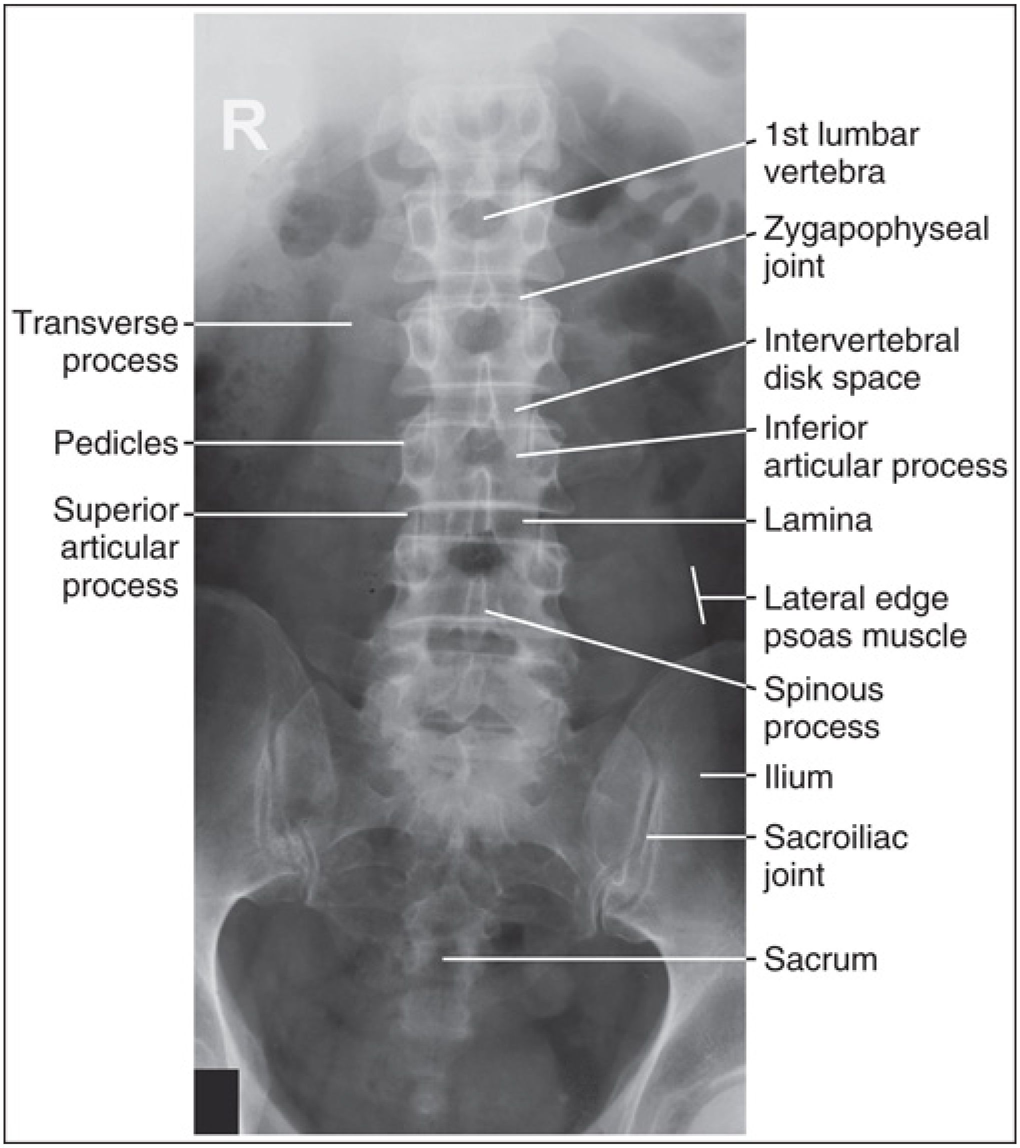


FIGURE 9.1 AP lumbar vertebral projection with accurate positioning.

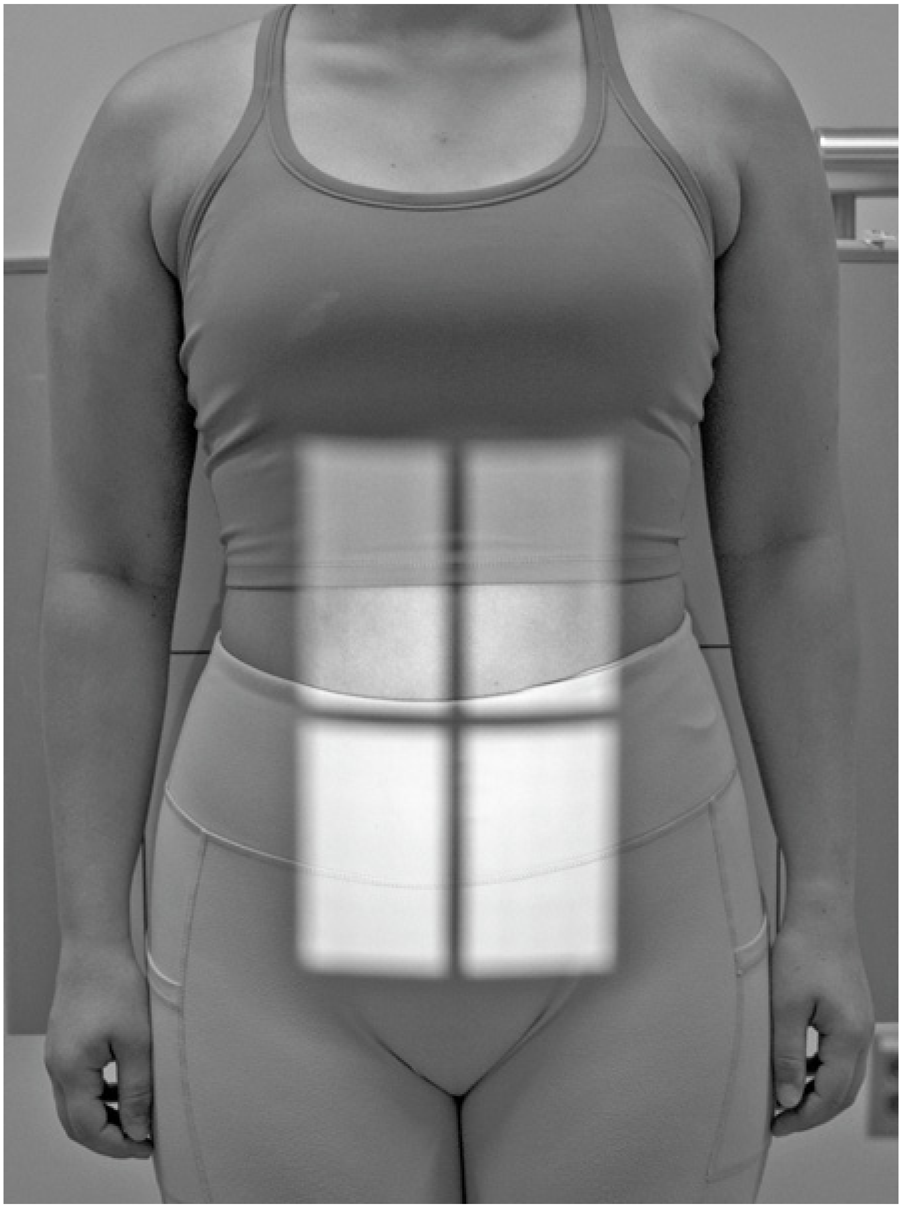


FIGURE 9.2 Proper patient positioning for AP lumbar vertebral projection.

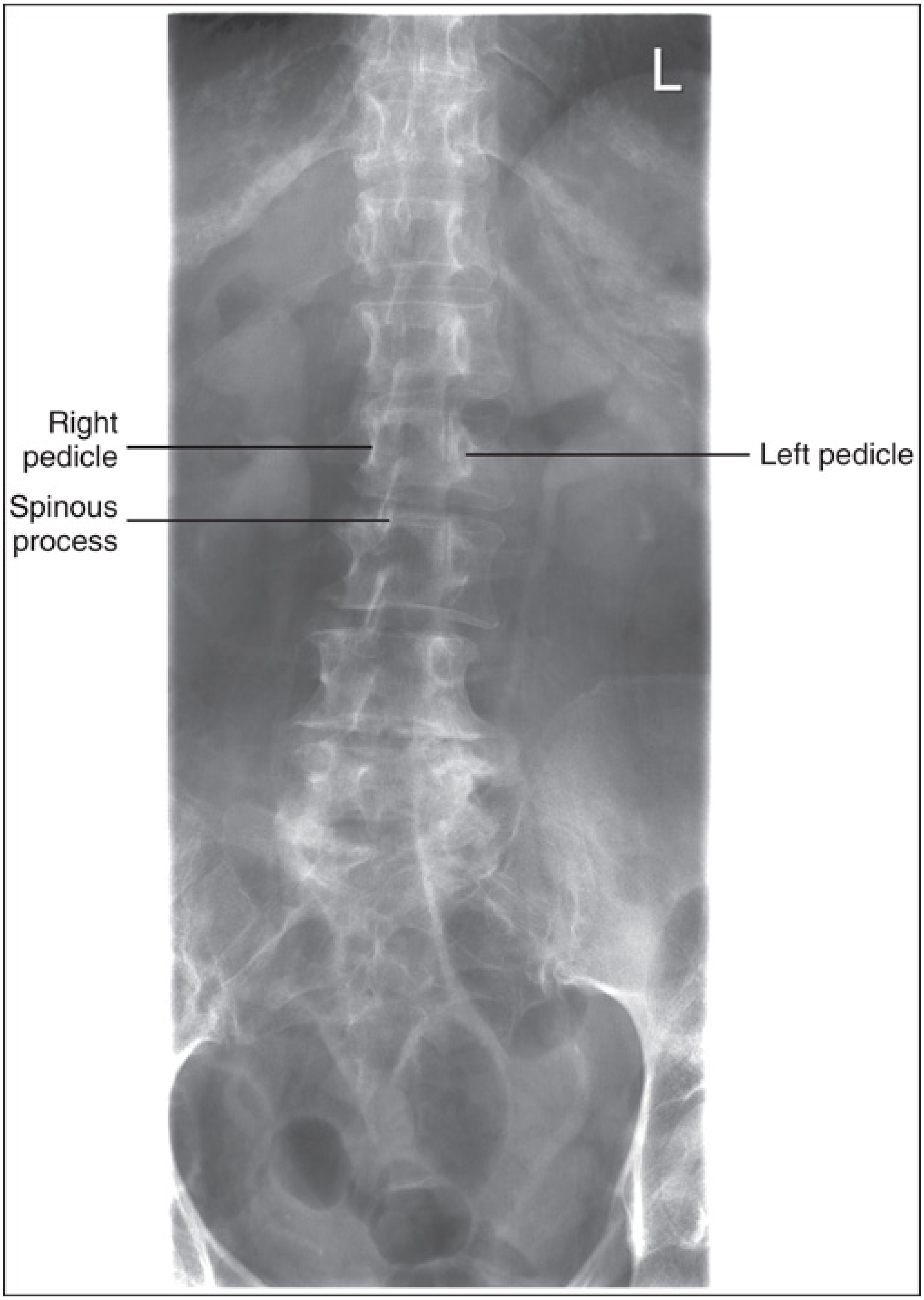


FIGURE 9.3 AP lumbar projection taken with left side positioning closer to the IR than right side.

TABLE 9.2

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

On rotation the spinous processes move away from the midline and closer to the pedicles on one side and away from the corresponding pedicles on the opposite side, resulting in different distances between the spinous processes and pedicles (**Fig. 9.3**). The side toward which the spinous processes rotate and that demonstrates the least distance from the spinous processes to the pedicles is the side of the patient positioned farther from the image receptor (IR). Lower lumbar rotation can also be detected by evaluating the position of the sacrum and coccyx within the pelvic inlet. If no rotation was present, they are centered within the pelvic inlet. On rotation, the sacrum and coccyx rotate toward the side of the pelvic inlet positioned farther from the IR.

Scoliotic Patient

In patients with spinal scoliosis, the lumbar bodies may appear rotated because of the lateral twisting of the vertebrae. Severe scoliosis is very obvious and is seldom mistaken for patient rotation (**Fig. 9.4**), whereas subtle scoliotic changes can be easily mistaken for rotation (**Fig. 9.5**). Although both conditions demonstrate unequal distances between the pedicles and spinous processes, certain clues can be used to distinguish subtle scoliosis from rotation. The long axis of a rotated vertebral column remains straight, whereas the scoliotic vertebral column demonstrates lateral deviation. If the lumbar vertebrae demonstrate rotation, it has been

caused by the rotation of the upper or lower torso. Rotation of the middle lumbar vertebrae (L3 and L4) does not occur unless the lower thoracic or upper or lower lumbar vertebrae also demonstrate rotation. On a scoliotic projection, the middle lumbar vertebrae may demonstrate rotation without corresponding upper or lower vertebral rotation.

FIGURE 9.4 AP lumbar projection taken of a patient with severe scoliosis.

Openness of Intervertebral Disk Spaces

When the patient is in a supine position with the legs extended or in a standing position, the lumbar vertebrae have an exaggerated lordotic curvature (**Fig. 9.6**). This curvature makes it impossible for all of the x-rays

to be aligned parallel with the intervertebral disk spaces and perpendicular to the vertebral bodies (**Fig. 9.7**). Obtaining an AP lumbar projection with the patient in these positions results in the upper (L1 and L2) and lower (L4 and L5) vertebrae demonstrating closed intervertebral disk spaces and distorted vertebral bodies, and a foreshortened sacrum that is positioned at a greater distance from the pubis symphysis (**Fig. 9.8**).

FIGURE 9.5 AP lumbar projection taken of a patient with subtle scoliosis.

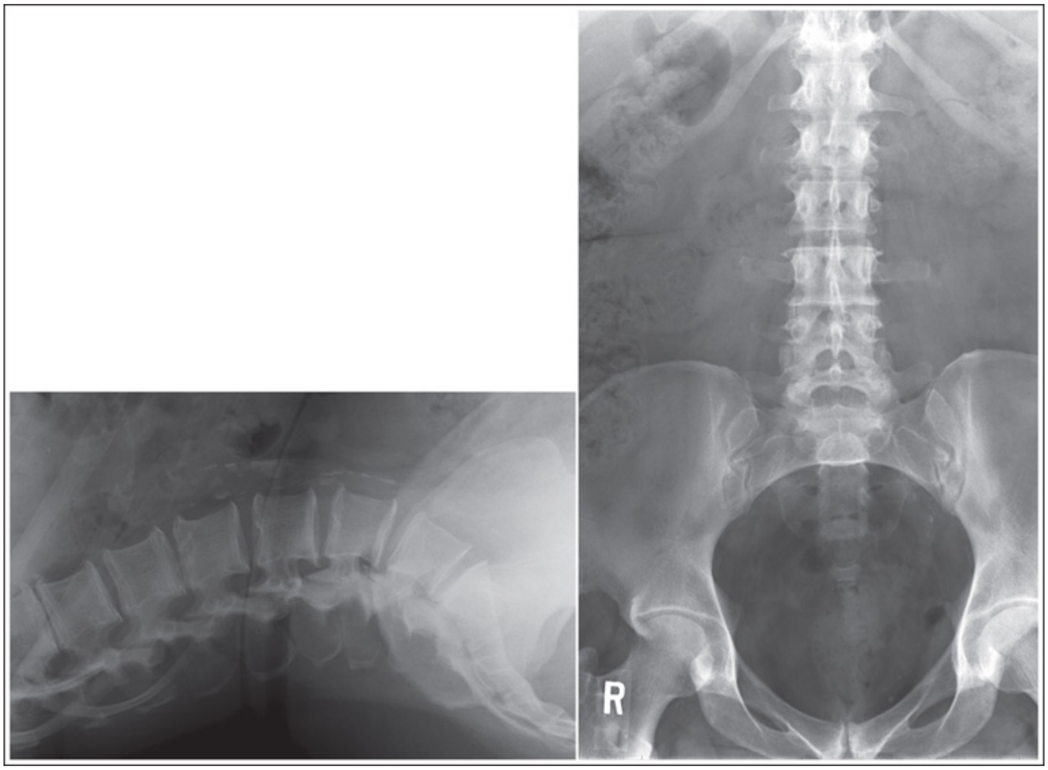


FIGURE 9.6 Lateral and AP lumbar projections taken on the same patient demonstrating intervertebral disk space alignment.

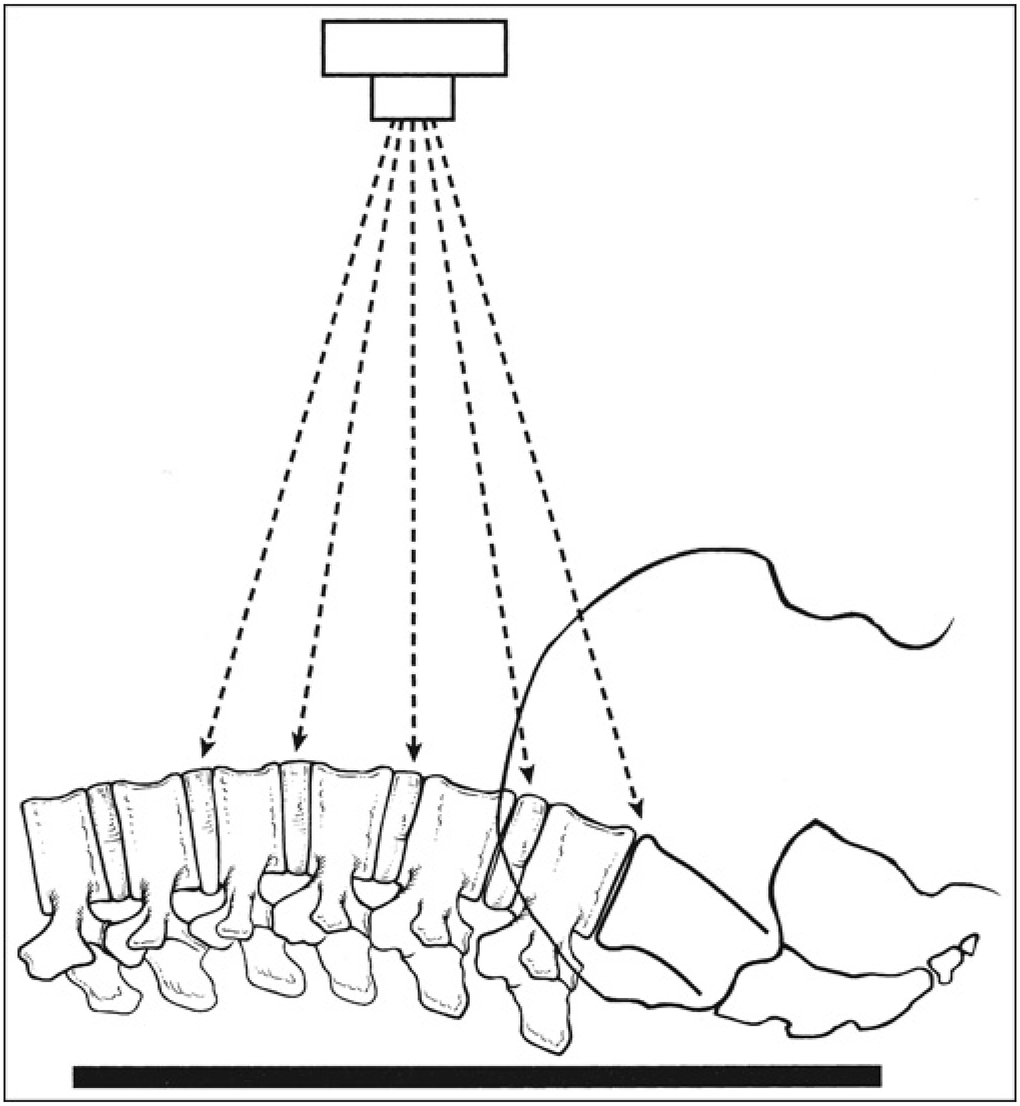


FIGURE 9.7 Alignment of CR and lumbar vertebrae when the legs are not flexed.

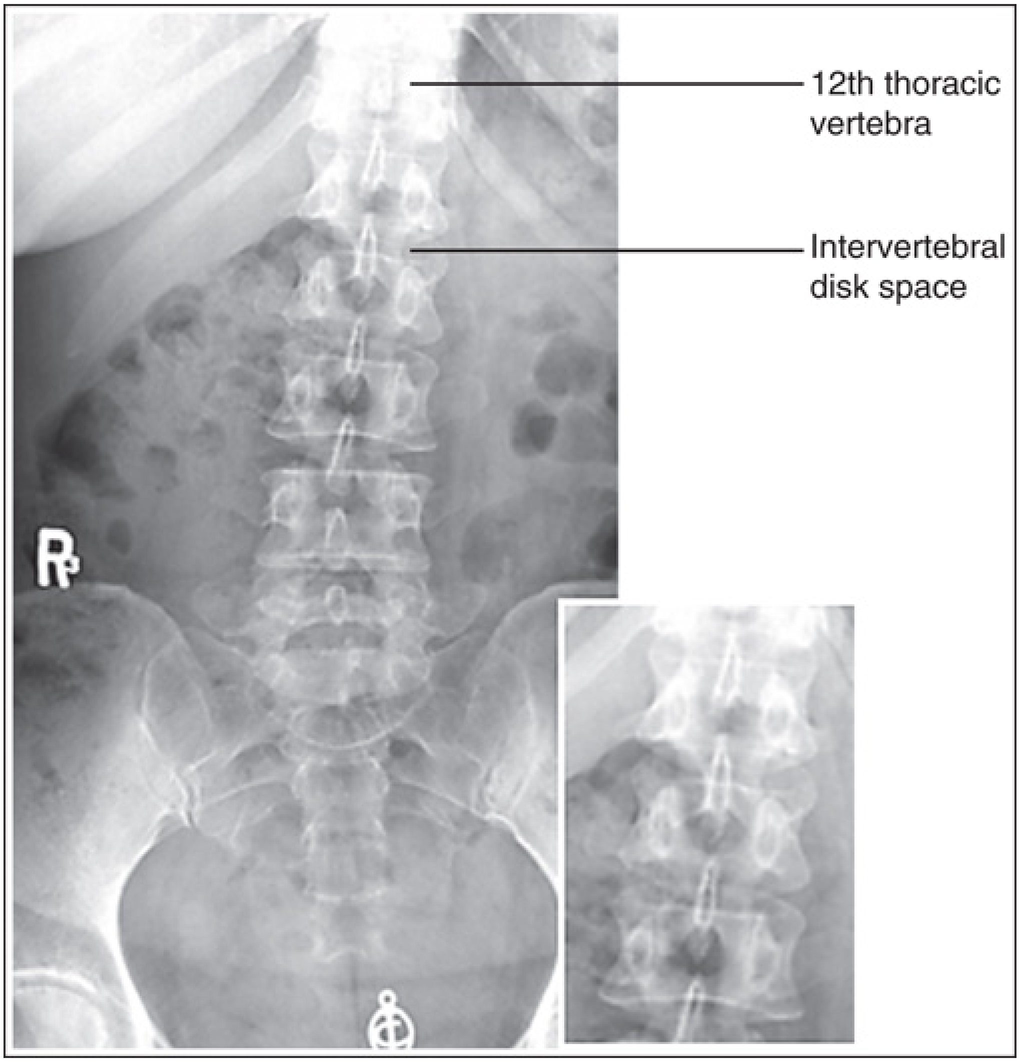


FIGURE 9.8 AP lumbar projection taken without the knees and hips flexed.

9.9).

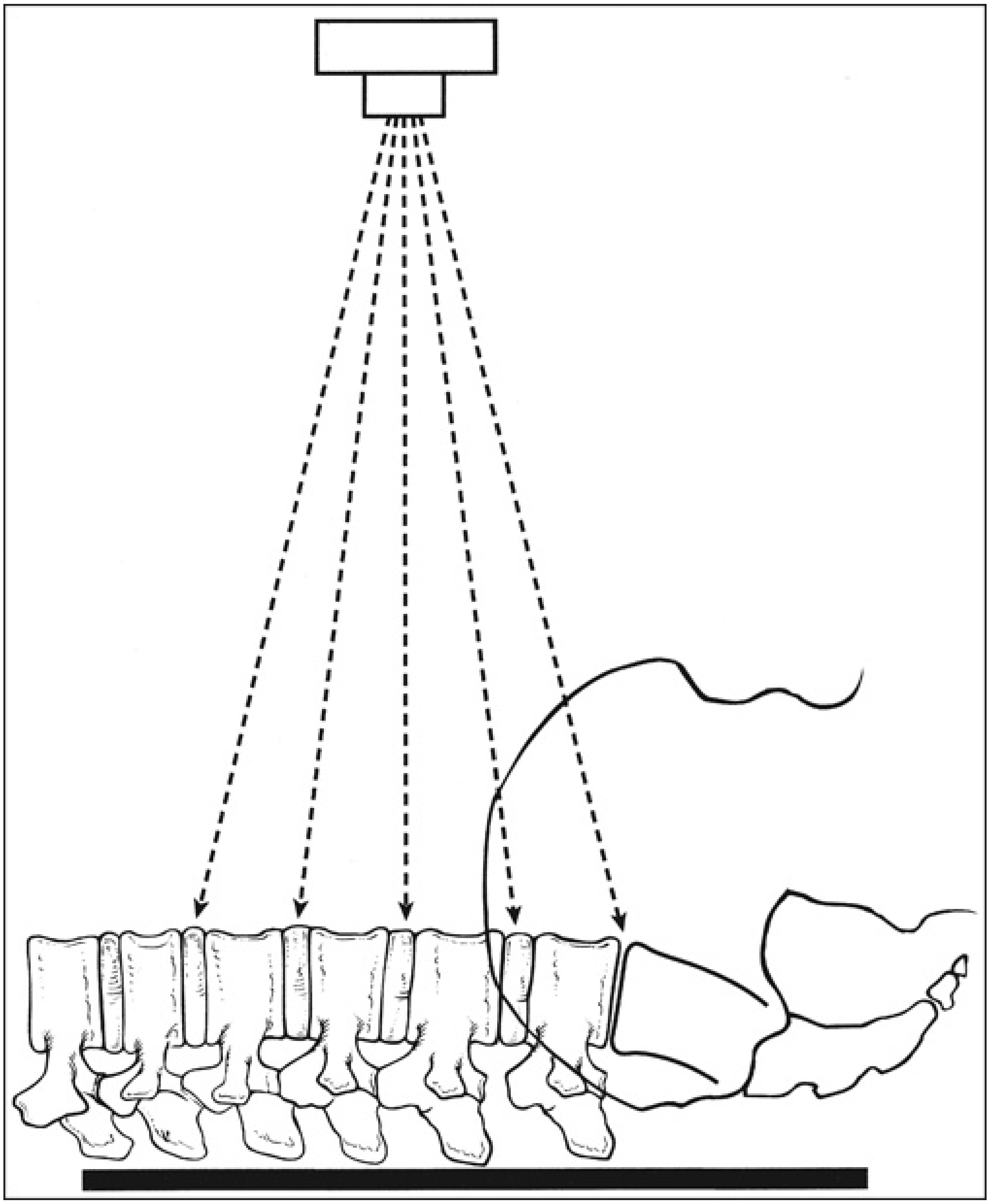


FIGURE 9.9 Alignment of CR and lumbar vertebrae when the legs are flexed.

To reduce the lordotic curvature of the lumbar vertebral column and better align the intervertebral disk spaces parallel with and the vertebral bodies perpendicular to the central ray (CR) for the supine position, flex the knees and hips until the lower back rests against the imaging table (**Fig. 9.9**).

AP Lumbar Analysis Practice

IMAGE 9.1

Analysis

The distance from the left pedicles to the spinous process is narrower than the same distance from the right pedicles to the spinous process. The patient was rotated toward the right side (right posterior oblique [RPO] rotation).

Correction

Rotate the patient toward the left side until the midcoronal plane is aligned parallel with the IR.

Lumbar Vertebrae: AP Oblique Projection (RPO and LPO Positions)

See **Table 9.3** and **Figs. 9.10** and **9.11**.

AP or PA Projection

This examination can be performed using an AP or PA oblique projection. In the AP oblique projection (RPO and left posterior oblique [LPO] positions; see **Fig. 9.11**), the zygapophyseal joints of interest are placed closer to the IR. In the posteroanterior (PA) oblique projection (RAO and LAO positions), the zygapophyseal joints of interest are positioned farther from the IR, resulting in greater magnification.

Scottie Dogs and Accurate Lumbar Obliquity

The accuracy of an AP oblique projection is often judged by the demonstration of five Scottie dogs stacked on top of one another. **Fig. 9.12** is a close-up of an accurately positioned oblique lumbar vertebra with the Scottie dog parts outlined and labeled. It should be noted that the Scottie dogs can be identified even on oblique projections that have been obtained with more or less than the required 45 degrees of obliquity. Judge the openness of each zygapophyseal joint to determine whether the lumbar vertebrae have been adequately rotated.

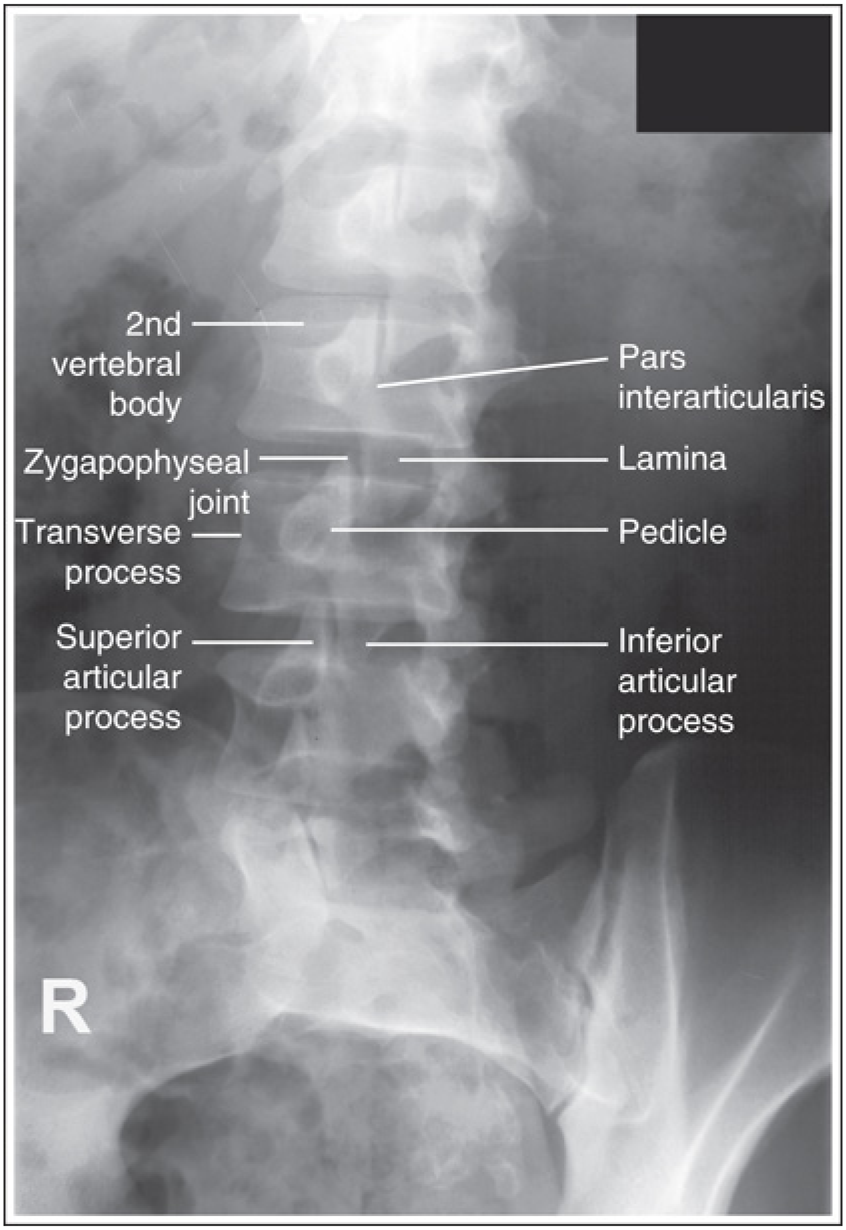


FIGURE 9.10 AP oblique lumbar vertebral projection with accurate positioning.

TABLE 9.3

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

Insufficient Vertebral Obliquity

If a lumbar vertebra was insufficiently rotated to position the superior and inferior articular processes (ear and front leg of Scottie dog) in profile, the corresponding zygapophyseal joint is closed, the pedicle (eye of Scottie dog) is situated closer to the lateral vertebral body border, and more of the lamina (body of Scottie dog) is demonstrated (**Fig. 9.13**).

FIGURE 9.11 Proper patient positioning for AP oblique lumbar vertebral projection.

Excessive Vertebral Obliquity

If a lumbar vertebra was rotated more than needed to position the superior and inferior articular processes in profile, the corresponding zygapophyseal

joint is closed, the pedicles are demonstrated closer to the vertebral body midline, and less of the lamina is demonstrated (**Fig. 9.14**).

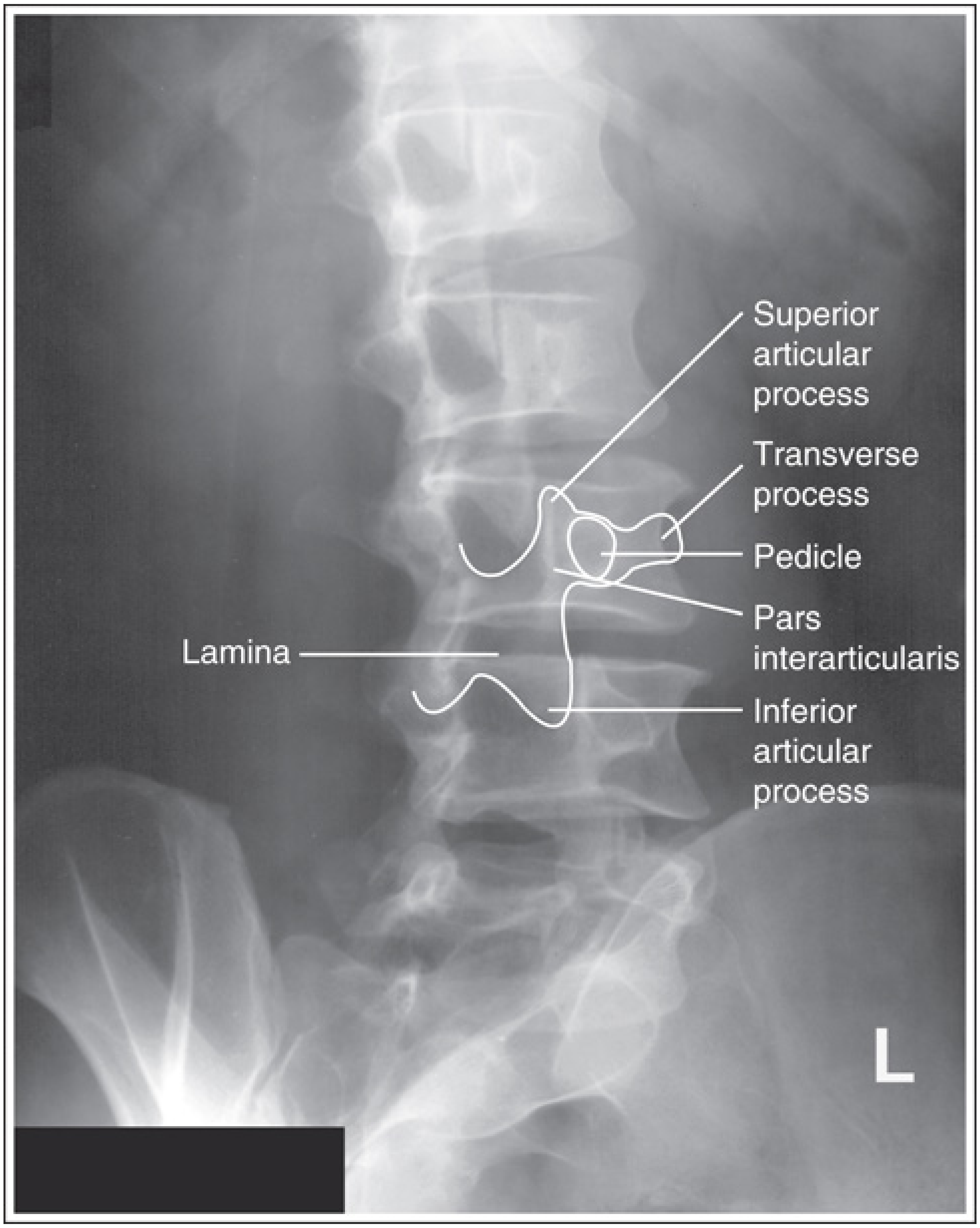


FIGURE 9.12 Identifying “Scottie dogs” and lumbar anatomy.

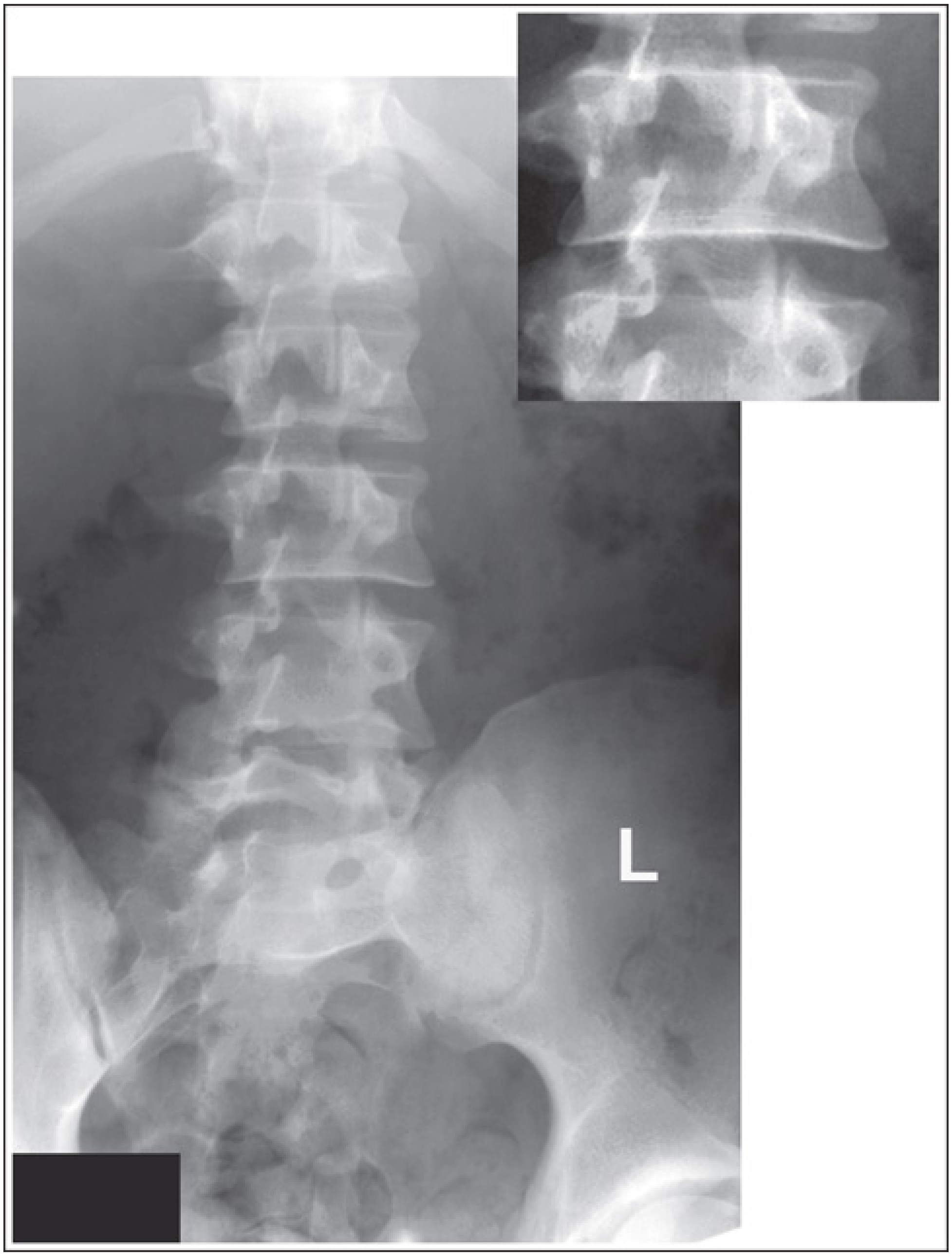


FIGURE 9.13 AP oblique lumbar projection taken with insufficient patient rotation.

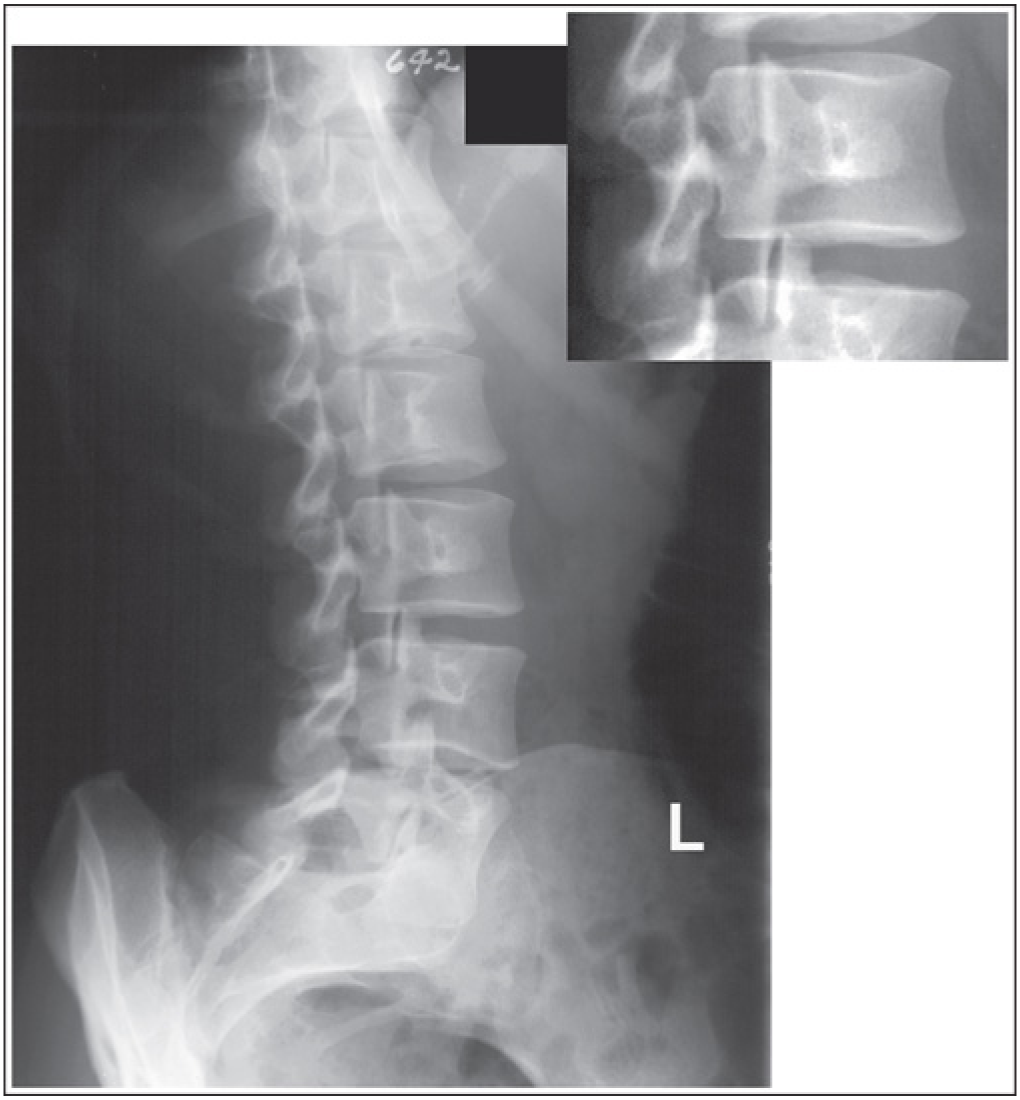


FIGURE 9.14 AP oblique lumbar projection taken with excessive patient rotation.

AP Oblique Lumbar Analysis Practice

IMAGE 9.2

Analysis

The superior and inferior articular processes are not in profile, the corresponding zygapophyseal joints are closed, and the pedicles are demonstrated closer to the vertebral body midline. The patient was rotated more than 45 degrees.

Correction

Decrease the degree of rotation until the midcoronal plane is at a 45-degree angle with the IR.

Lumbar Vertebrae: Lateral Projection

See **Table 9.4** and **Figs. 9.15** and **9.16**.

Rotation

The upper and lower lumbar vertebrae can demonstrate rotation independently or simultaneously, depending on which section of the torso is rotated. If the thorax was rotated but the pelvis remained in a lateral position, the upper lumbar vertebrae demonstrate rotation. If the pelvis was rotated but the thorax remained in a lateral position, the lower lumbar vertebrae demonstrate rotation. Rotation can be detected on a lateral lumbar projection by evaluating the superimposition of the right and left posterior surfaces of the vertebral bodies. On a nonrotated lateral lumbar projection, these posterior surfaces are superimposed, appearing as one. On rotation, these posterior surfaces are not superimposed, but one is demonstrated anterior to the other (**Fig. 9.17**). Because the two sides of the vertebrae, thorax, and pelvis are mirror images, it is very difficult to determine from a rotated lateral lumbar projection which side of the patient was rotated anteriorly and which posteriorly, unless the twelfth posterior ribs are demonstrated. The twelfth posterior rib that demonstrates the greatest magnification and is situated inferiorly is adjacent to the side of the patient positioned farther from the IR.

Openness of Intervertebral Disk Spaces

When the patient is placed in a lateral recumbent position, the center of the lumbar vertebral column may sag toward the IR (**Fig. 9.18**) because of lateral flexion or may be straight but tilted at an angle with the IR. This will most often occur when imaging patients with broad shoulders and narrow hips or wide hips and a narrow waist. A slight bit of sagging is acceptable and will actually help to better align the x-ray beams with the intervertebral disk spaces. If the lumbar column demonstrates excessive sagging or tilting, the diverging x-ray beams will not be aligned parallel with the intervertebral disk spaces and perpendicular to the vertebral bodies and the resulting projection will demonstrate closed disk spaces and distorted vertebral bodies (**Fig. 9.19**). For a patient who has excessive lumbar column sagging, it may be necessary to tuck a radiolucent sponge between the lateral body surface and imaging table, just superior to the iliac crest, elevating the sagging area. The sponge should be thick enough to bring the lumbar vertebral column close to parallel with the IR (see **Fig. 9.16**). For a patient whose lumbar column is tilted with the IR, open disk spaces and undistorted vertebral bodies can be obtained by angling the CR as needed to align it perpendicular to the lumbar vertebral column.

TABLE 9.4

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

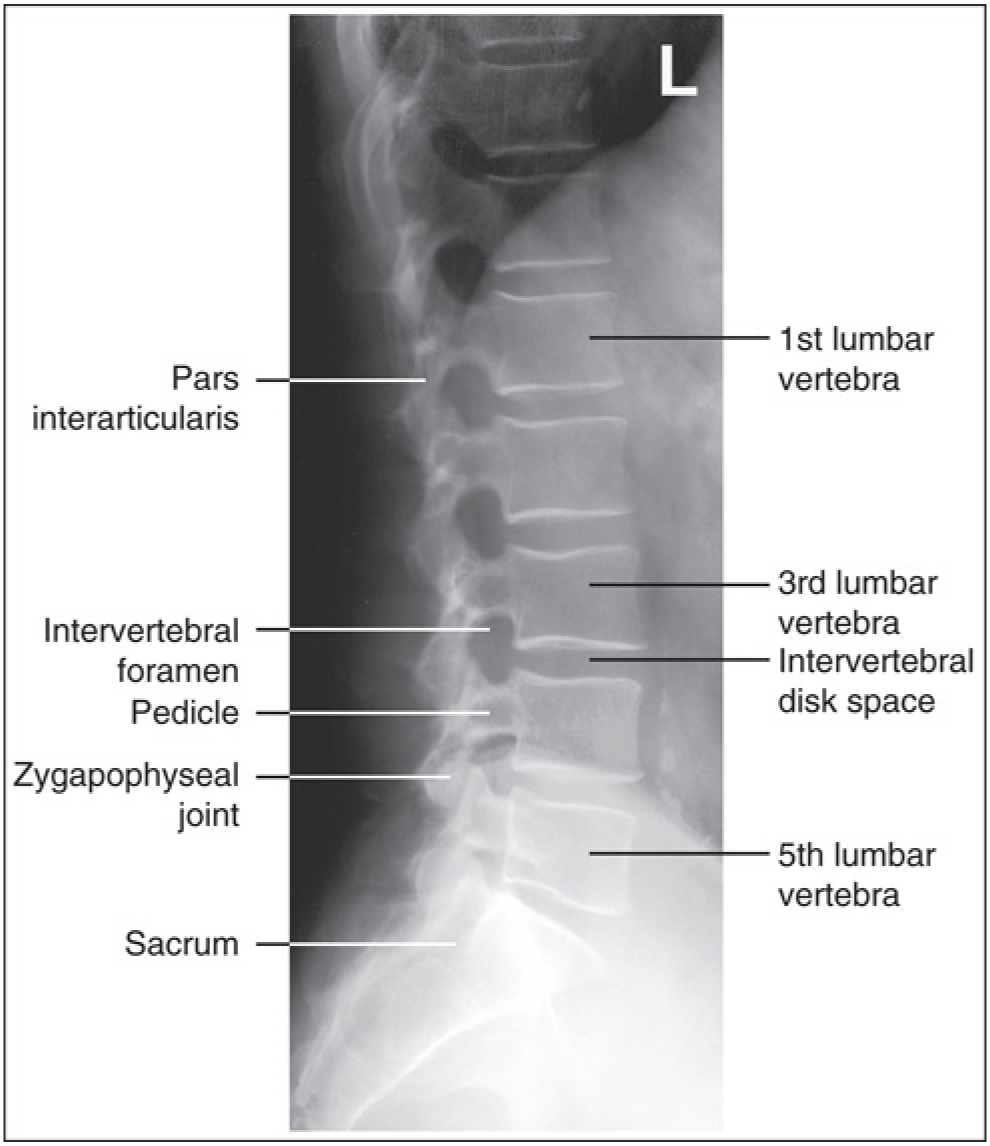


FIGURE 9.15 Lateral lumbar vertebral projection with accurate positioning.

FIGURE 9.16 Proper patient positioning for lateral lumbar vertebral projection.

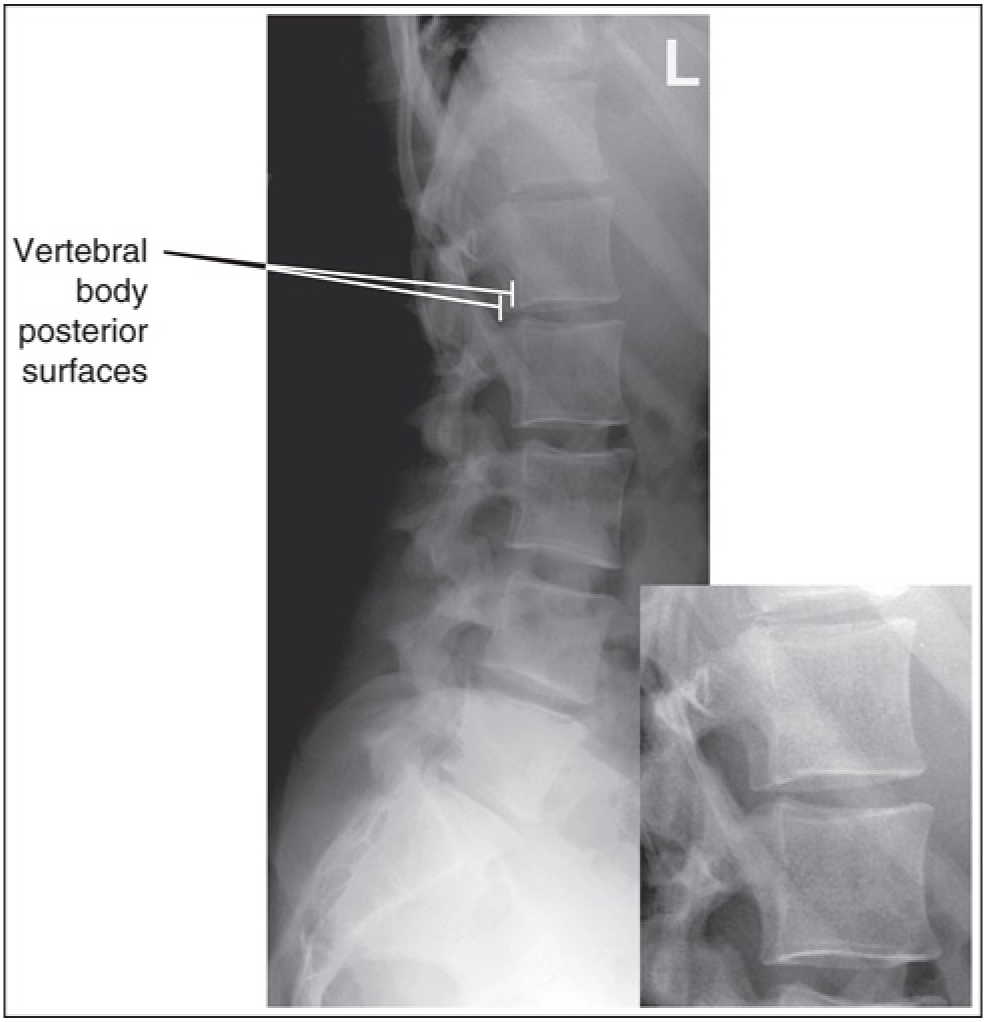


FIGURE 9.17 Lateral lumbar vertebral projection taken with right side rotated posteriorly.

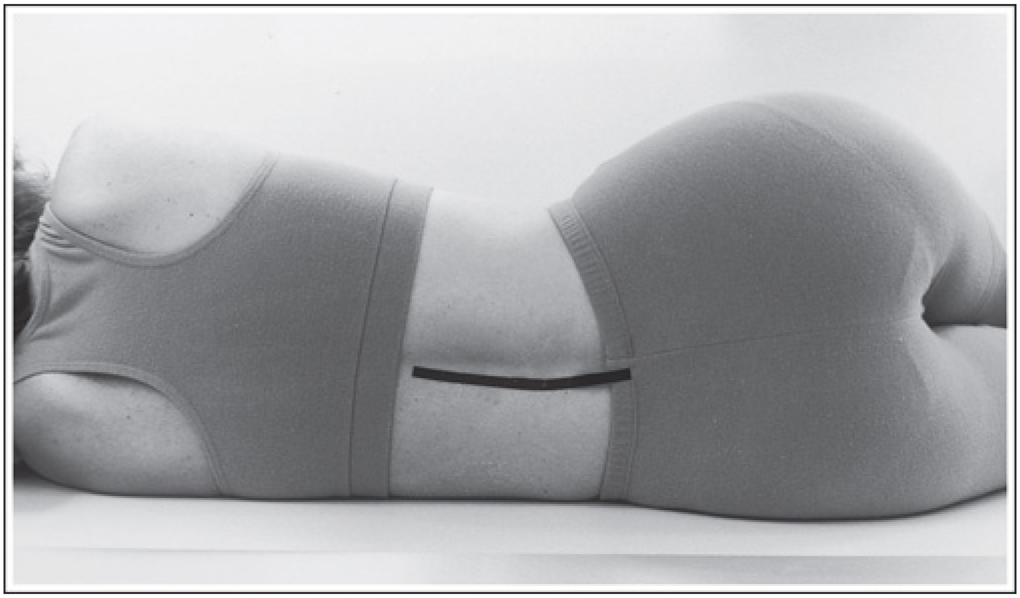


FIGURE 9.18 Poor alignment of vertebral column and imaging table.

FIGURE 9.19 Lateral lumbar projection taken with vertebral column tilted with IR.

Scoliotic Patient

Whether the patient is lying on the right or left side for the lateral lumbar vertebrae is insignificant, although left-side positioning is often easier for the technologist. One exception to this guideline is the scoliotic patient, who should be placed on the imaging table so that the CR is directed into the spinal curve to better demonstrate open intervertebral disk spaces (**Fig.**

9.20). Determine how the lumbar curve is directed by viewing the patient's back and following the curve of the vertebral column and evaluating the AP projection. **Fig. 9.21** demonstrates AP and lateral lumbar vertebrae projections taken on a patient with a scoliotic lumbar column that curves toward the right side of the patient. The lateral projection was obtained with the patient in a left lateral position, resulting in the CR divergence going against the spinal curve and the projection demonstrating closed intervertebral joint spaces.

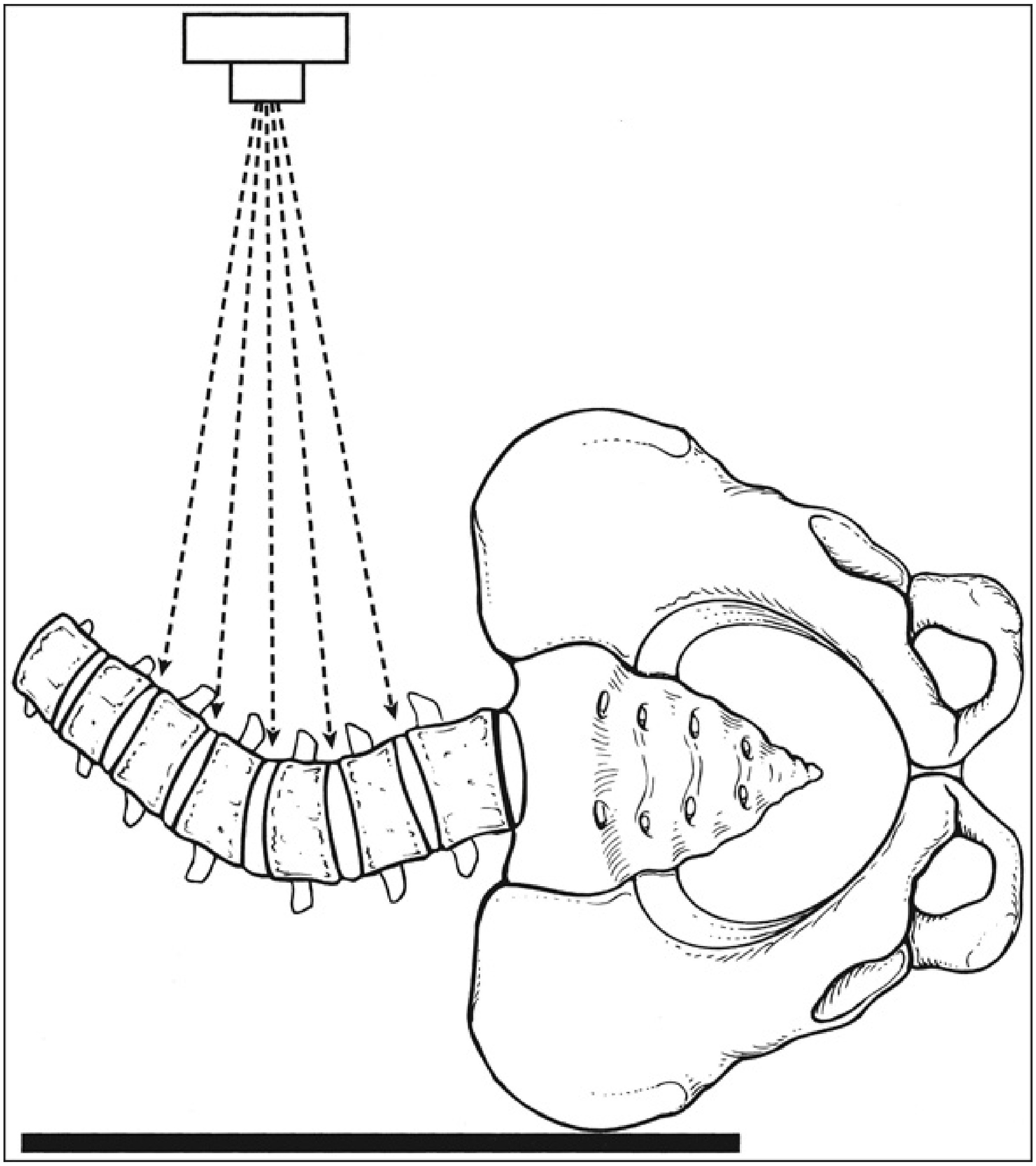


FIGURE 9.20 Alignment of CR and scoliotic lumbar vertebral column.

Flexion and Extension of Lumbar Vertebrae

If the lumbar vertebrae are being imaged in the lateral projection to demonstrate AP vertebral mobility, two laterals are taken, one with the patient in maximum flexion and one in maximum extension. The x-ray order can be for an upright or supine position. For maximum flexion,

instruct the patient to flex the shoulders, upper thorax, and knees anteriorly, rolling into a tight ball (**Fig. 9.22**). The resulting projection should meet all the requirements listed for a lateral projection with accurate positioning, except that the lumbar vertebral column demonstrates a very straight longitudinal axis without lordotic curvature (**Fig. 9.23**).

For maximum extension, instruct the patient to arch the back by extending the shoulders, upper thorax, and legs as far posteriorly as possible (**Fig. 9.24**). The resulting projection should meet all the requirements listed for a lateral projection with accurate positioning, except that the lumbar vertebral column demonstrates an increased lordotic curvature (**Fig. 9.25**).

Lumbar Vertebrae and IR Center Alignment

Aligning the long axis of the lumbar vertebral column with the collimator's longitudinal light line allows tight collimation, which will reduce patient dose and is necessary to reduce the production of scatter radiation. The lumbar vertebrae are located in the posterior half of the torso. Their exact posterior location can be determined by palpating the anterior superior iliac spine (ASIS) and posterior iliac wing (at the level of the sacroiliac joint) of the side of the patient situated farther from the IR. The long axis of the lumbar vertebral column is aligned with the coronal plane that is situated halfway between these two structures (**Fig. 9.26**).

Supplementary Projection of the L5-S1 Lumbar Region

A coned-down projection of the L5-S1 lumbar region is required when a lateral lumbar projection is obtained that demonstrates insufficient contrast resolution in this area or the L5-S1 joint space is closed. In patients with wide hips, it is often difficult to set exposure factors that adequately demonstrate the upper and lower lumbar regions concurrently. For these patients, set exposure factors that adequately demonstrate the upper lumbar

region. Then obtain a tightly collimated lateral projection of the L5-S1 lumbar region to demonstrate the lower lumbar area. See the description for the lateral projection of the L5-S1 lumbosacral junction later in this chapter.

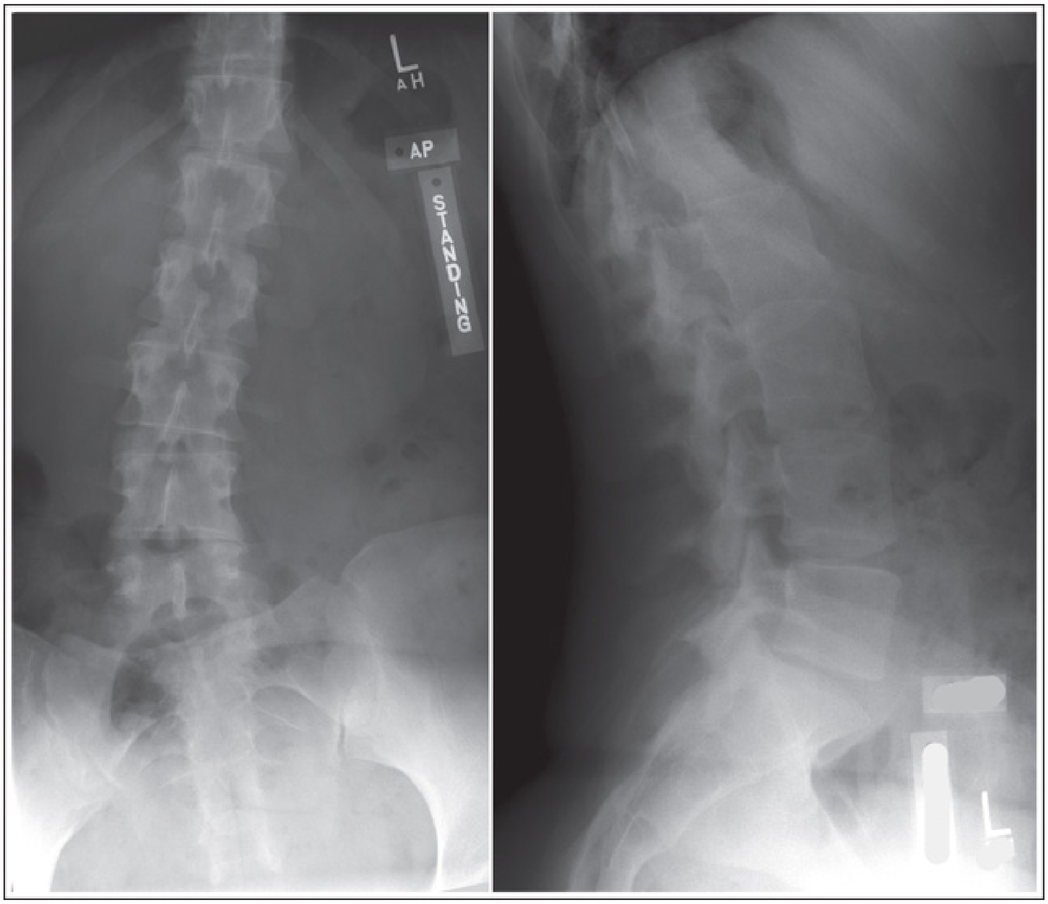


FIGURE 9.21 AP and lateral lumbar vertebrae projections of patient with spinal scoliosis. CR was against curve for the lateral projection.

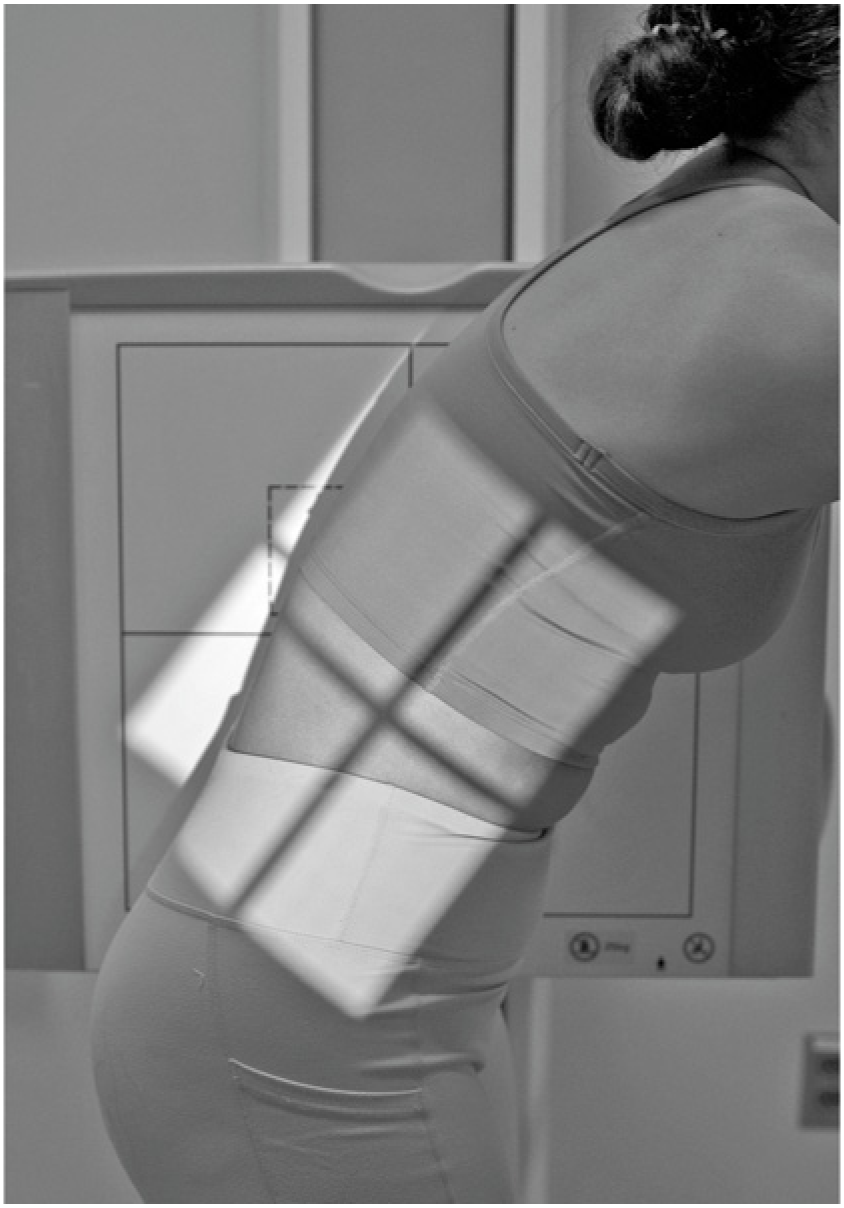


FIGURE 9.22 Proper patient positioning for lateral lumbar vertebral projection with vertebral flexion.

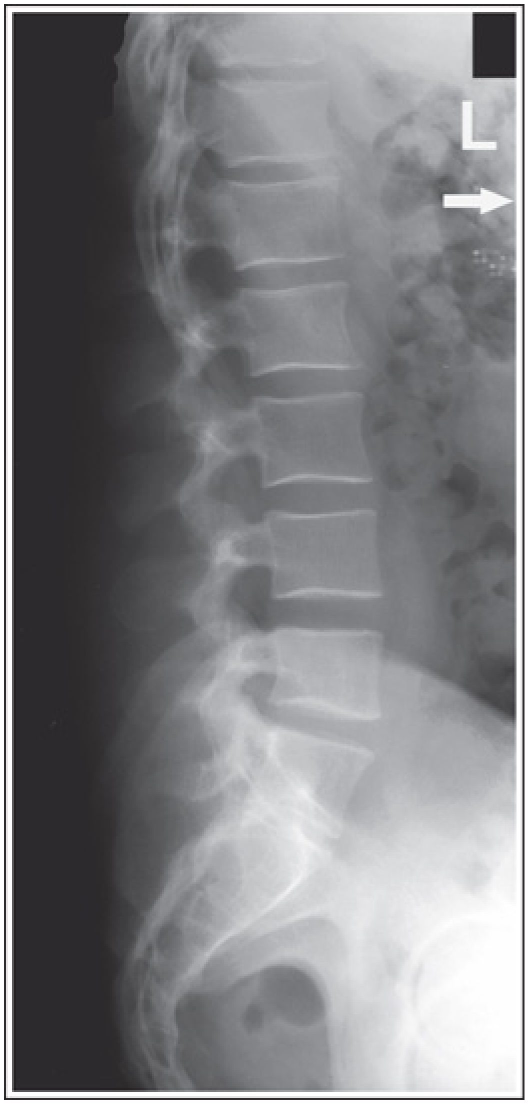


FIGURE 9.23 Lateral lumbar projection taken with patient in flexion.

FIGURE 9.24 Proper patient positioning for lateral lumbar vertebral projection with vertebral extension.

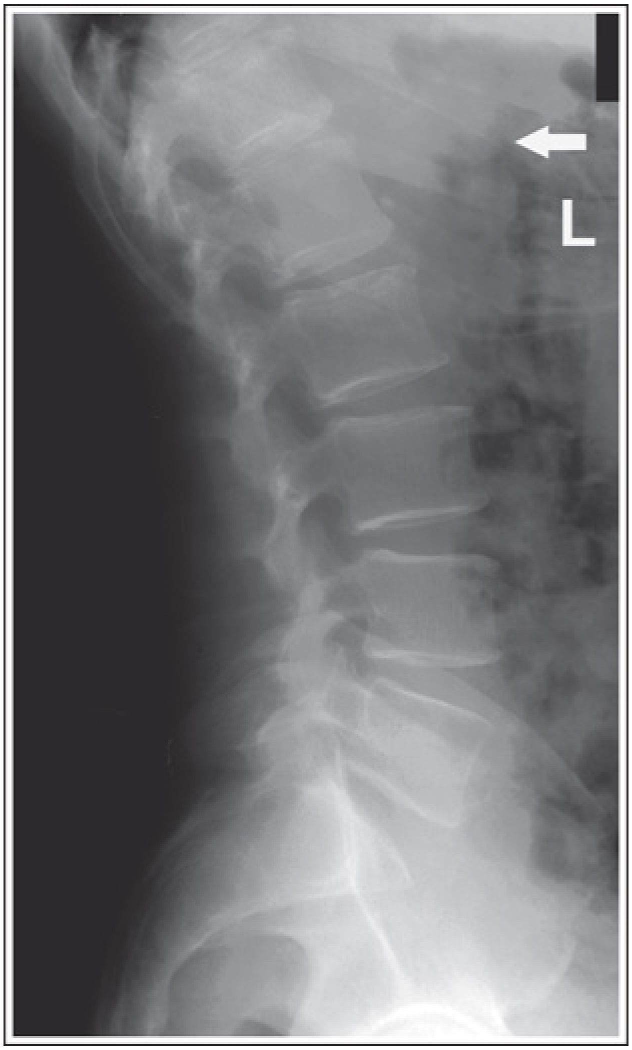


FIGURE 9.25 Lateral lumbar projection taken with patient in an extension.

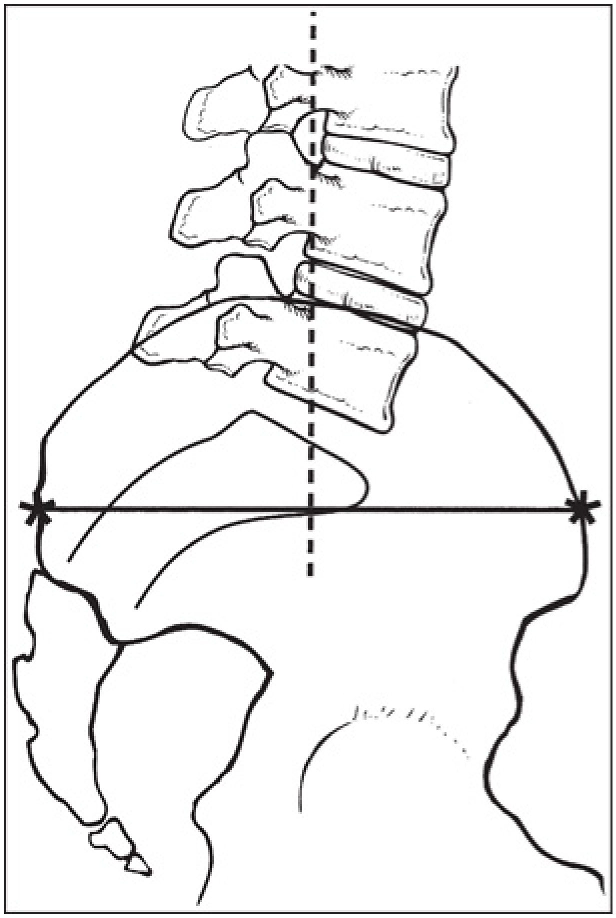


FIGURE 9.26 Proper CR centering and long axis placement. *Asterisks* identify the posterior iliac wing and anterior superior iliac spines.

Lateral Lumbar Vertebrae Analysis Practice

IMAGE 9.3

Analysis

The posterior surfaces of the vertebral bodies are not superimposed. The right side of the patient was rotated anteriorly.

Correction

Rotate the right side of the patient posteriorly until the midcoronal plane is aligned perpendicular with the IR.

L5-S1 Lumbosacral Junction: Lateral Projection

See **Table 9.5** and **Figs. 9.27** and **9.28**.

Rotation

Rotation can be detected on a lateral L5-S1 projection by evaluating the openness of the intervertebral foramen and the superimposition of the greater sciatic notches and alignment of the femoral heads, when seen. On rotation, neither the greater sciatic notches are superimposed nor are the femoral heads aligned, but they are demonstrated one anterior to the other (**Fig. 9.29**). Because the two sides of the pelvis are mirror images, it is difficult to determine which side of the patient was rotated anteriorly and which posteriorly on a lateral L5-S1 lumbosacral junction projection with poor positioning. If the femoral heads are visible on the projection, they may be used to determine rotation as long as the vertebral column was not sagging and the L5-S1 disk space is open. The femoral head that is projected more inferiorly and demonstrates the greatest magnification is the one situated farther from the IR.

Openness of L5-SI Disk Space

The lumbar vertebral column is capable of lateral flexion (see discussion in lateral lumbar projection; see **Fig. 9.18**). If this flexion is not considered during positioning, the diverging x-ray beams will not be aligned parallel with the L5-S1 disk space and perpendicular to L5 or the long axis of the sacrum. Lateral lumbar flexion can be detected on an L5-S1 projection by evaluating the superimposition of the pelvic alae and the openness of the

L5-S1 disk space. A laterally flexed projection demonstrates the pelvic alae without superoinferior alignment and a closed L5-S1 disk space (**Fig. 9.30**).

Adjusting for the Sagging Vertebral Column

Two methods may be used to overcome the sagging vertebral column:

1. Place a radiolucent sponge between the lateral body surface and imaging table just superior to the iliac crest to elevate the vertebral column, aligning it parallel with the IR (see **Fig. 9.28**); use a perpendicular CR.
2. Leave the patient positioned as is and angle the CR caudally until it parallels the interiliac line (**Fig. 9.31**).

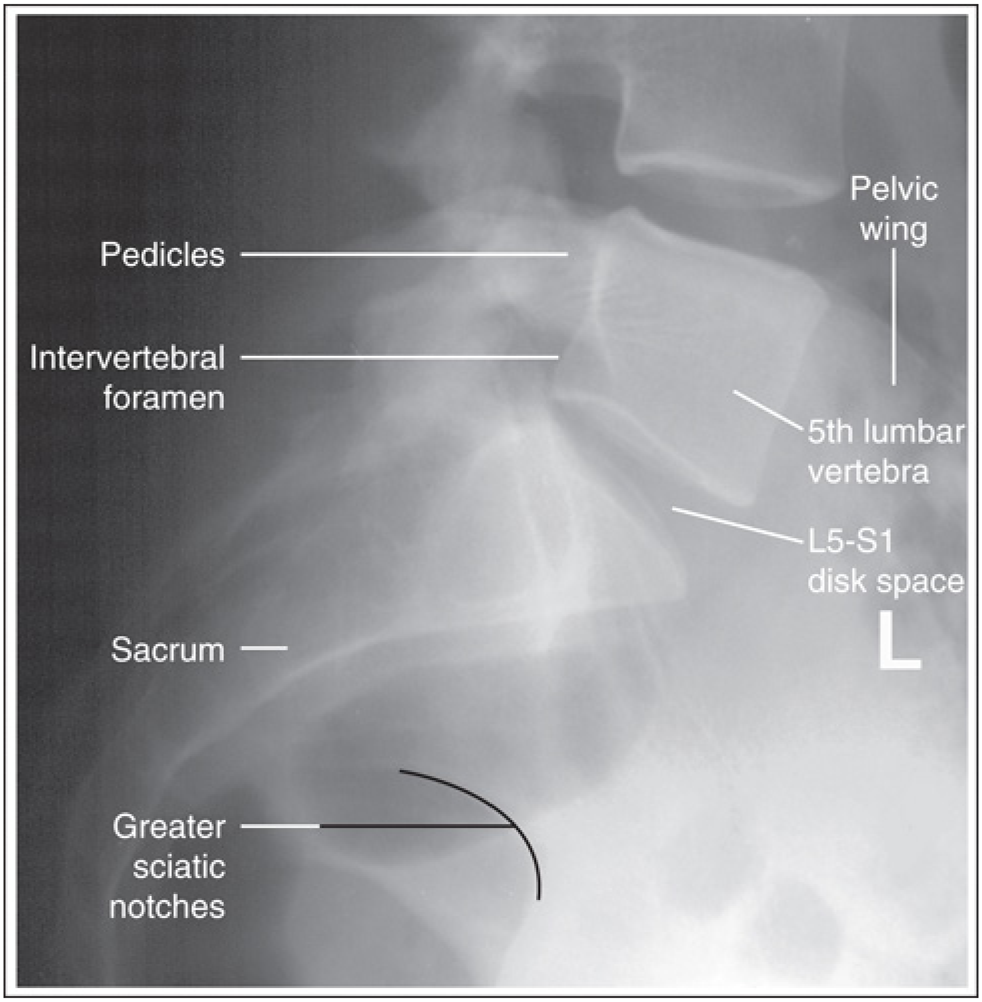


FIGURE 9.27 Lateral L5-S1 lumbosacral junction projection with accurate positioning.

FIGURE 9.28 Proper lateral L5-S1 lumbosacral junction positioning.

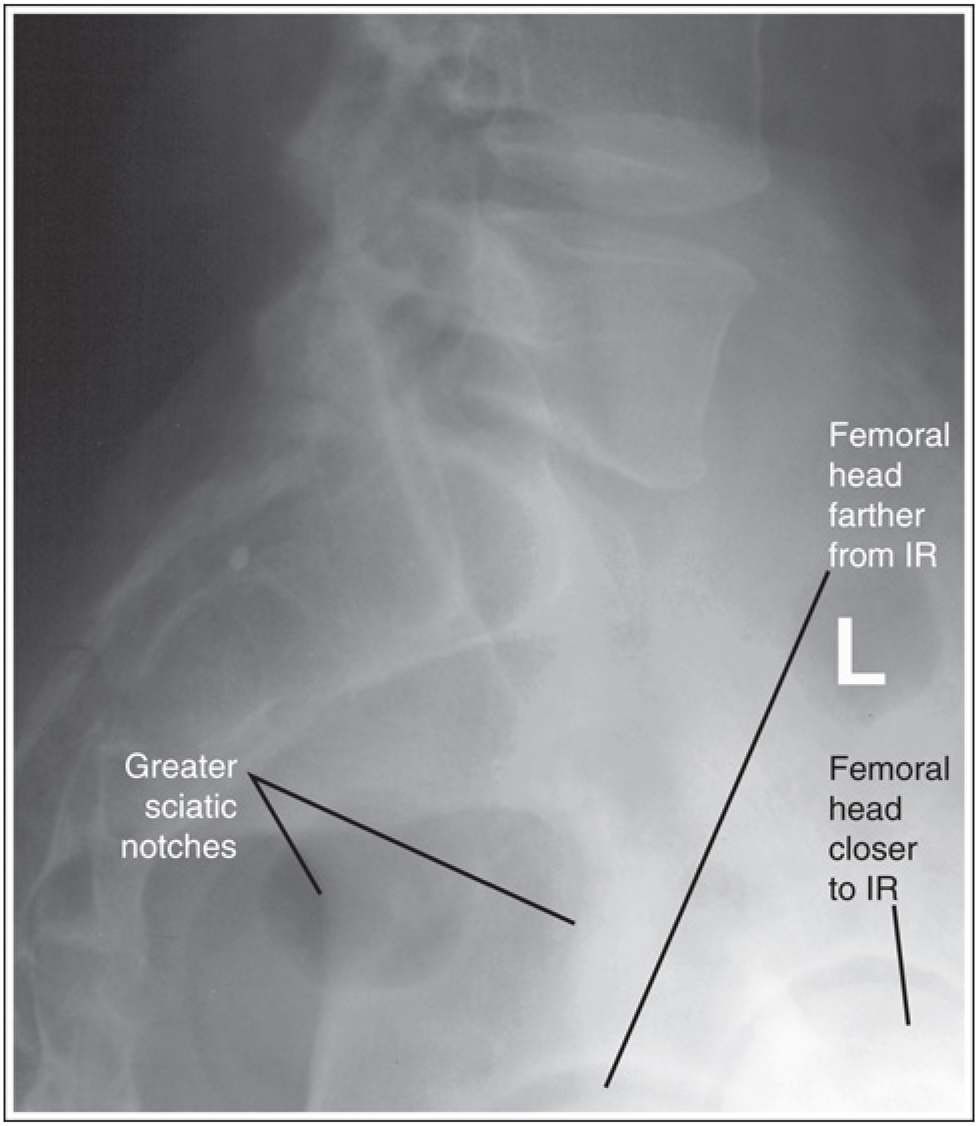


FIGURE 9.29 L5-S1 lateral lumbosacral junction projection taken with right side positioned posteriorly.

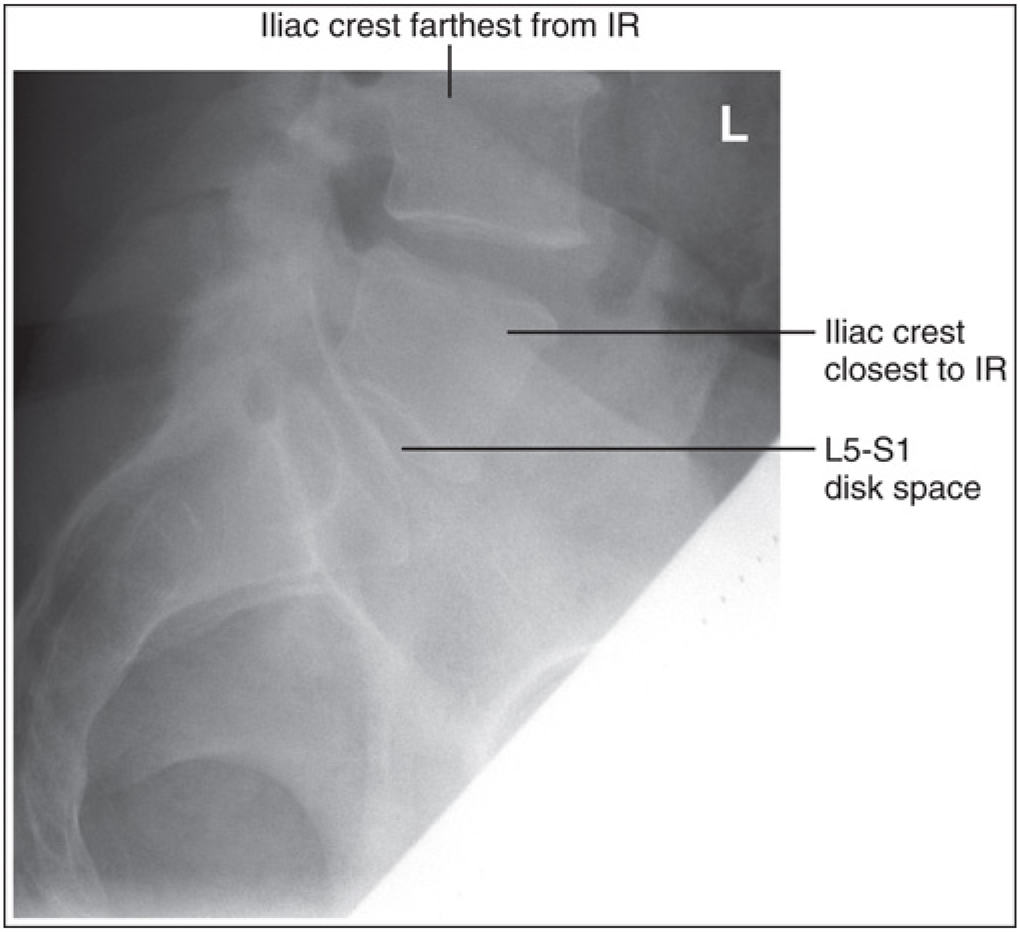


FIGURE 9.30 L5-S1 lateral lumbosacral junction projection taken without the vertebral column aligned parallel with the IR.

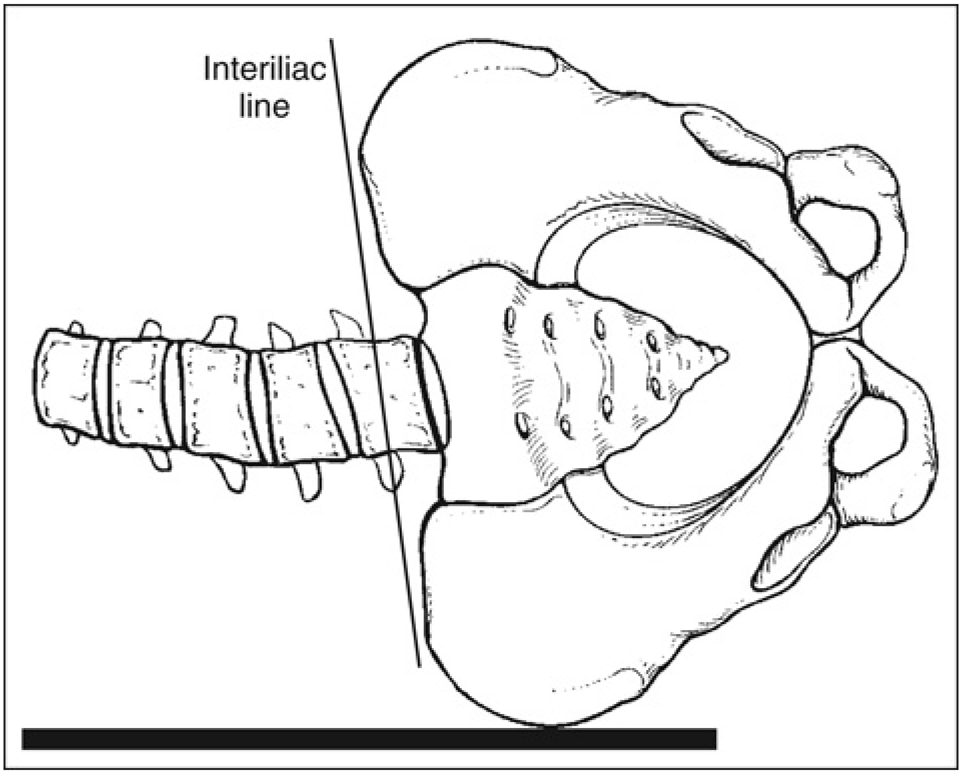


FIGURE 9.31 Adjusting for sagging curved vertebral column.

TABLE 9.5

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

Lateral L5-S1 Analysis Practice

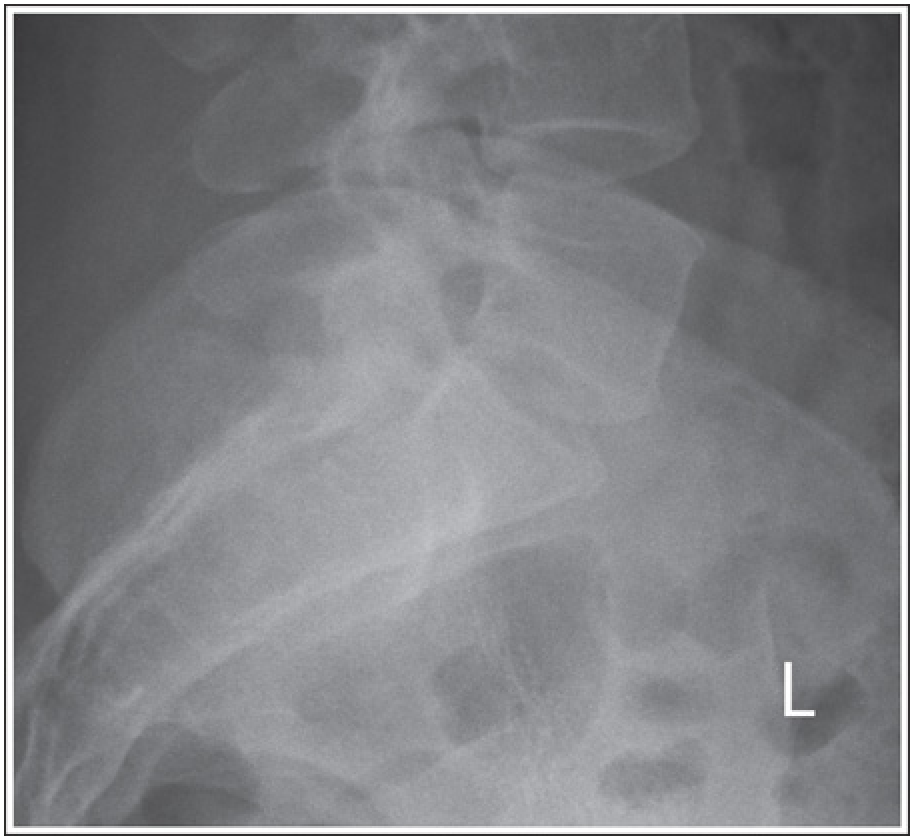


IMAGE 9.4

Analysis

The L5-S1 intervertebral disk space is closed, and the L5 vertebral body is distorted. The lumbar vertebral column was sagging toward the imaging table.

Correction

Place a radiolucent sponge between the patient's lateral body surface and imaging table to align the vertebral column parallel with the IR or angle the CR caudally until it parallels the interiliac line.

Sacrum: AP Axial Projection

See **Table 9.6** and **Figs. 9.32** and **9.33**.

Emptying Bladder and Rectum

The urinary bladder should be emptied before the procedure. It is also recommended that the colon be free of gas and fecal material. Elimination of urine, gas, and fecal material from the area superimposed over the sacrum improves its demonstration (**Fig. 9.34**).

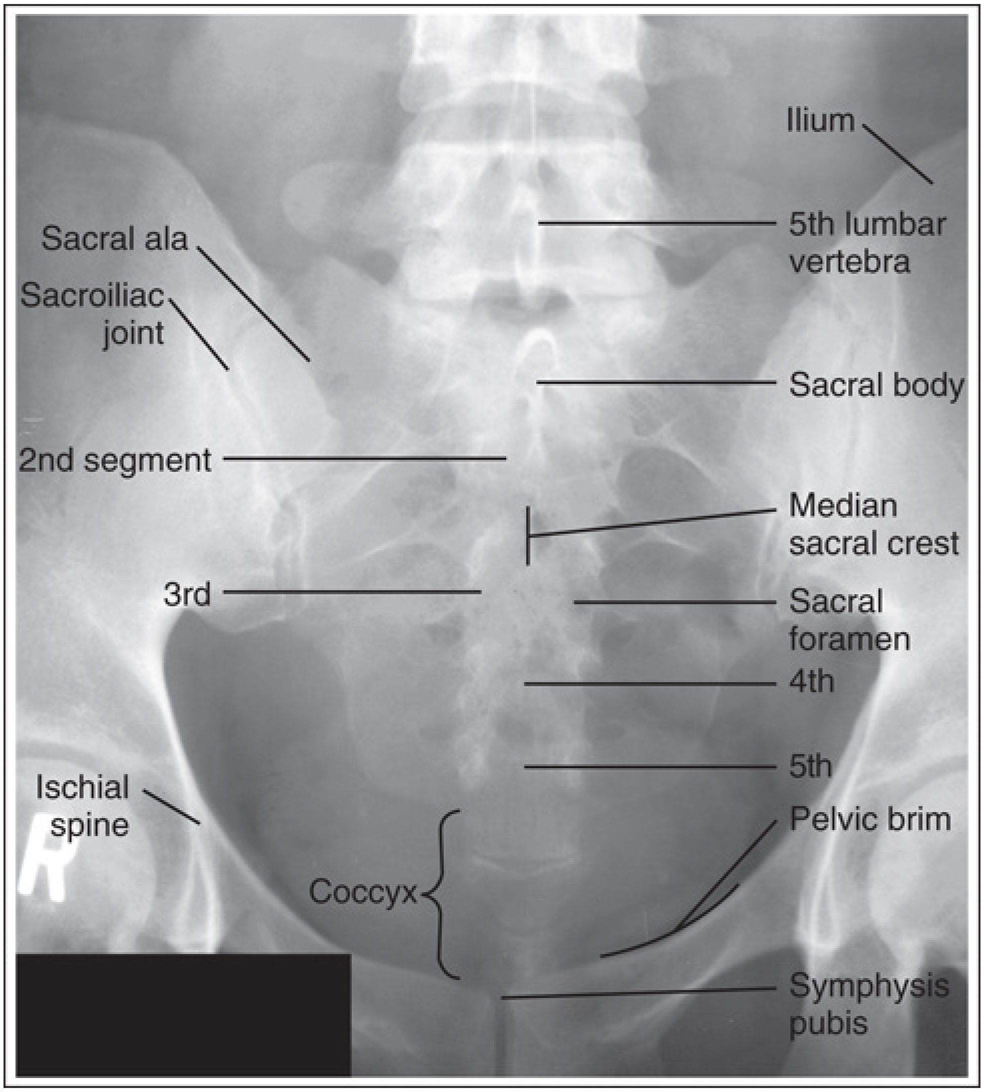


FIGURE 9.32 AP axial sacral projection with accurate positioning.

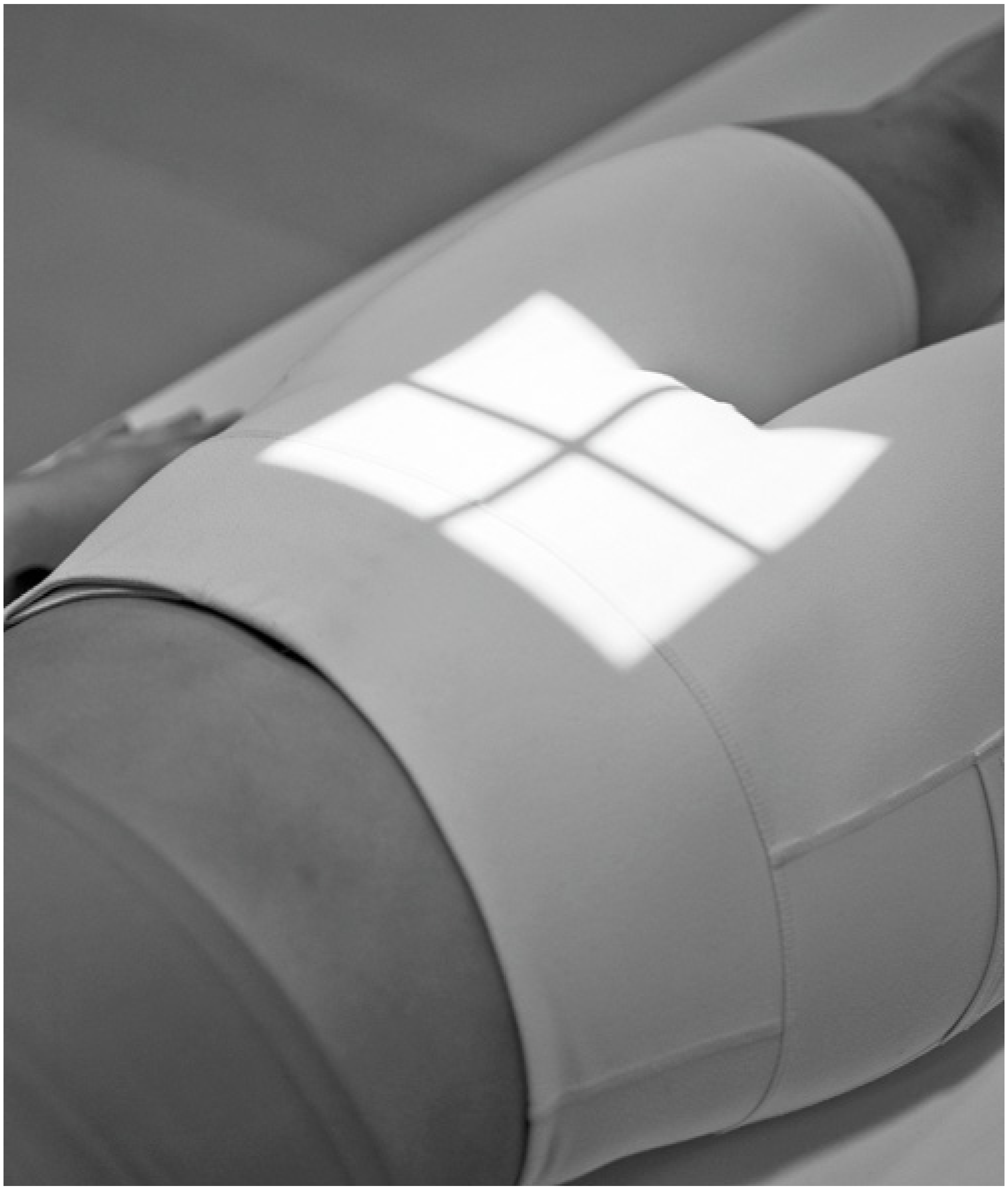


FIGURE 9.33 Proper patient positioning for AP axial sacral projection.

TABLE 9.6

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

Rotation

Rotation is effectively detected on an AP axial sacral projection by comparing the amount of iliac spine demonstrated without pelvic brim superimposition and by evaluating the alignment of the median sacral crest and coccyx with the pubis symphysis. If the patient was rotated away from the AP projection, the sacrum shifts toward the side positioned farther from the IR, and the pelvic brim and symphysis shift toward the side positioned closer to the IR. If the patient was rotated into an LPO position, the left ischial spine is demonstrated without pelvic brim superimposition, and the median sacral crest and coccyx are not aligned with the pubis symphysis but are rotated toward the right side (**Fig. 9.35**). If the patient is rotated into an RPO position, the opposite is true—the right ischial spine is demonstrated without pelvic brim superimposition, and the median sacral crest and coccyx are rotated toward the left side (**Fig. 9.36**).

FIGURE 9.34 AP axial sacral projection with fecal material superimposing the sacrum.

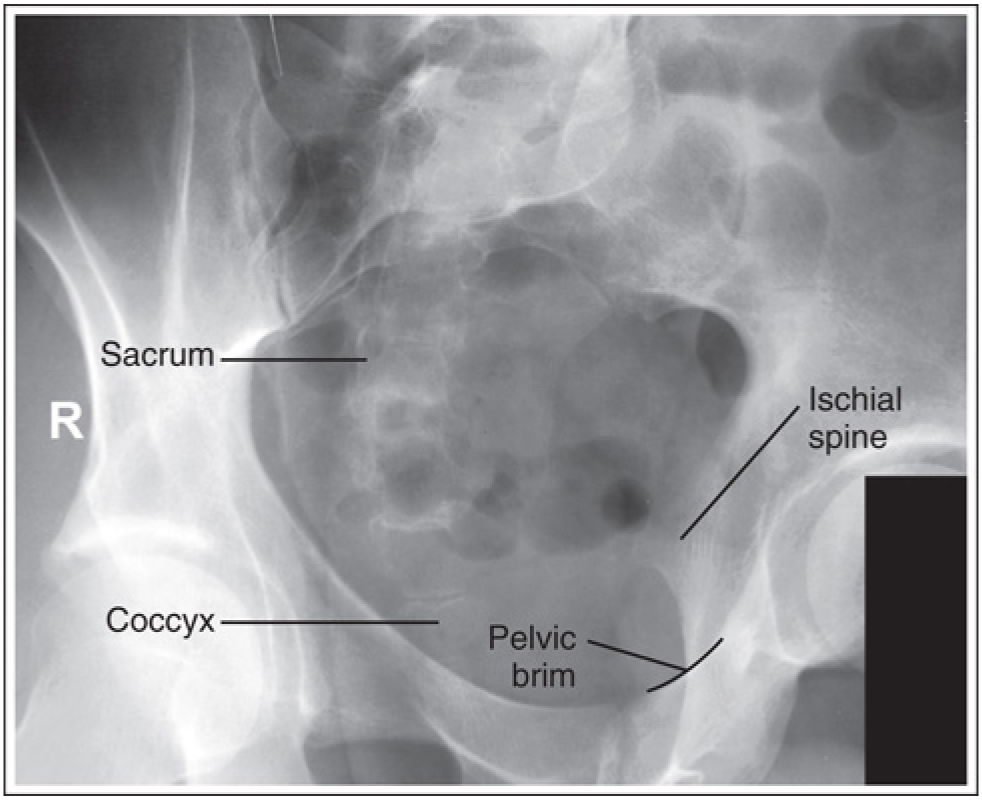


FIGURE 9.35 AP axial sacral projection taken with patient rotated onto the left side.

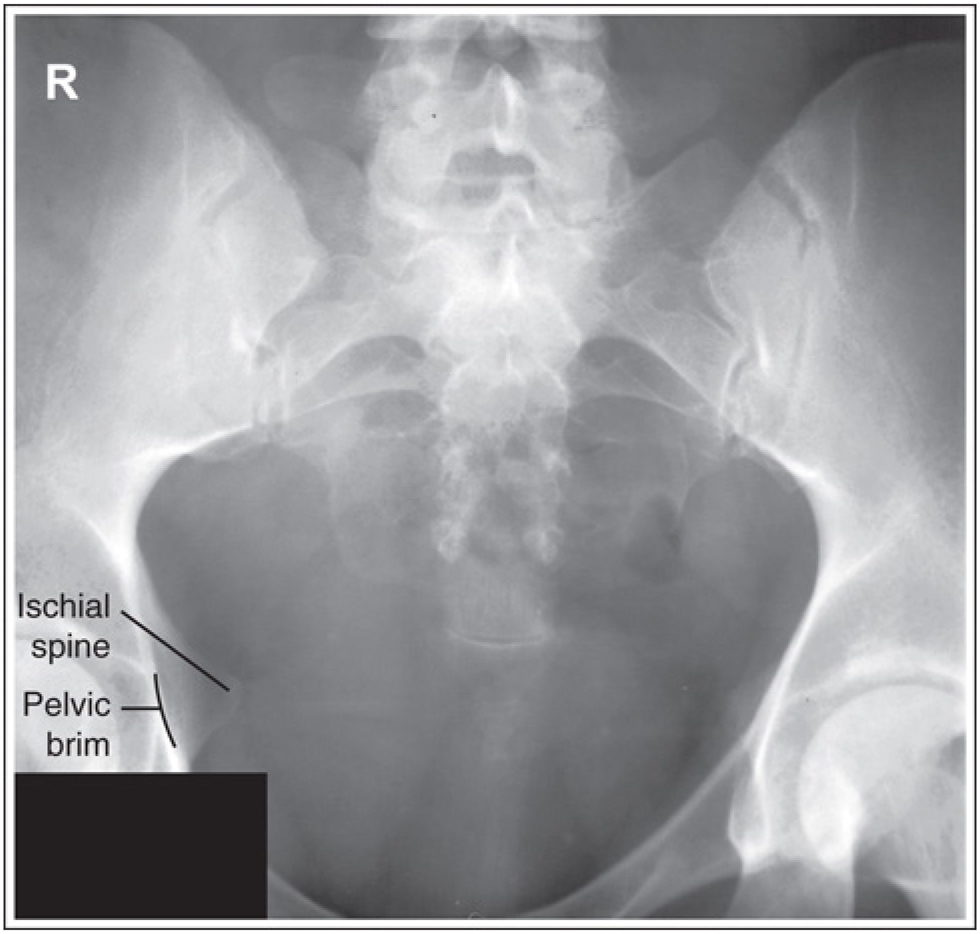


FIGURE 9.36 FIP axial sacral projection taken with the patient rotated onto the right side and insufficient cephalic CR angulation.

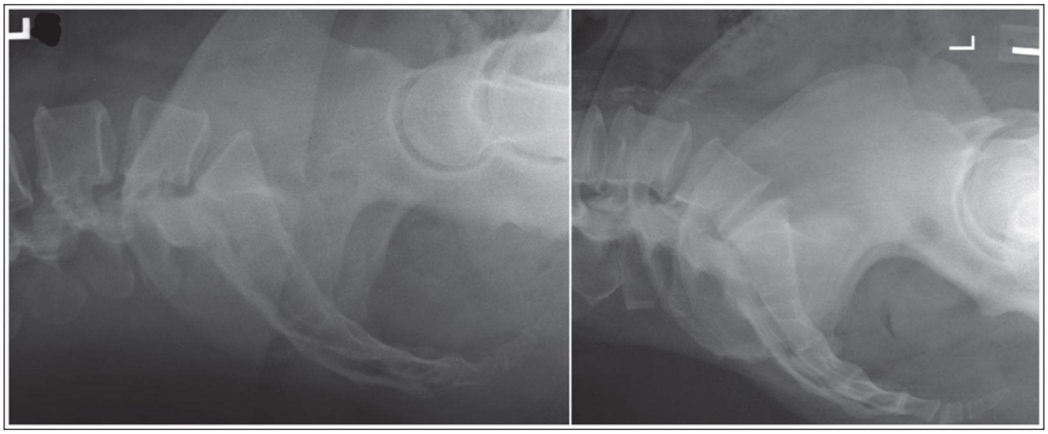


FIGURE 9.37 Two lateral sacrum projections demonstrating different degrees of lordotic curvature of the lumbar vertebral column.

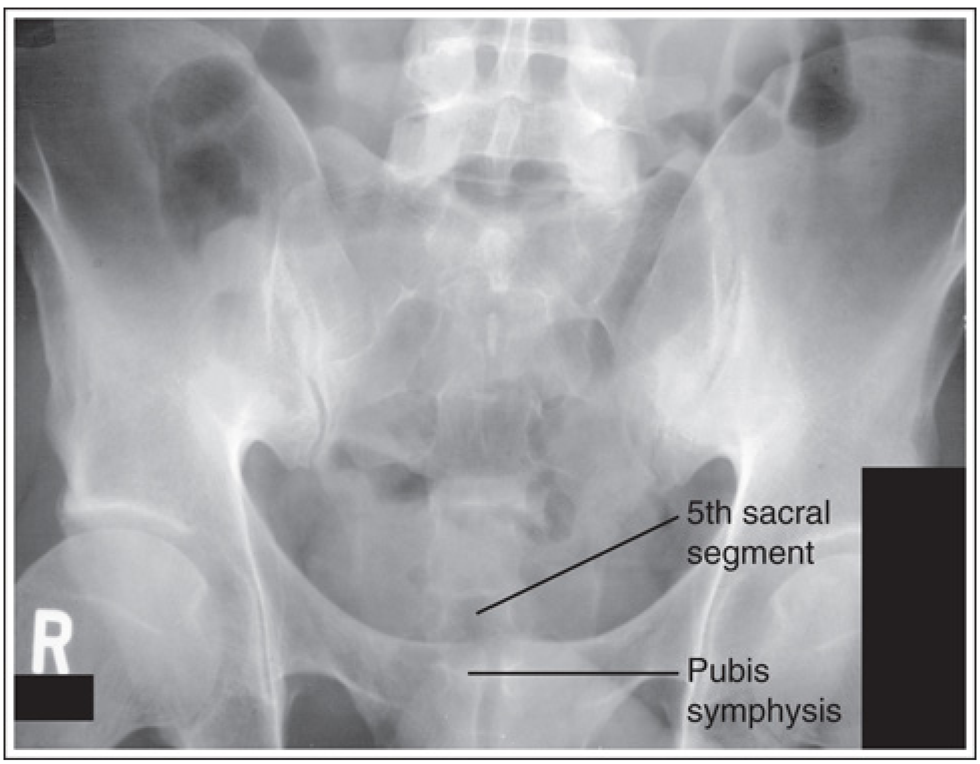


FIGURE 9.38 AP axial sacral projection taken with excessive cephalic CR angulation.

CR Angulation and Sacral Foreshortening

When the patient is in a supine position with the legs extended, the lumbar vertebral column demonstrates a lordotic curvature and the sacrum demonstrates a kyphotic curvature (**Fig. 9.37**). To demonstrate the sacrum without foreshortening, the CR needs to be aligned perpendicular to its long axis, which for most patients requires a 15-degree cephalad CR angulation. Because the degree of lumbar lordotic curvature can vary between patients and the pelvis and the sacrum tilt more with the IR as the lumbar lordotic curvature increases, the CR angle may need to be adjusted to best demonstrate the AP sacrum without foreshortening. If an AP axial sacral projection was taken with an insufficient CR angulation, the first, second, and third sacral segments are foreshortened (see **Fig. 9.36**). If the projection was taken with excessive CR angulation, the sacrum will be elongated and the pubis symphysis will superimpose the inferior sacral segments (**Fig. 9.38**).

AP Sacrum Analysis Practice

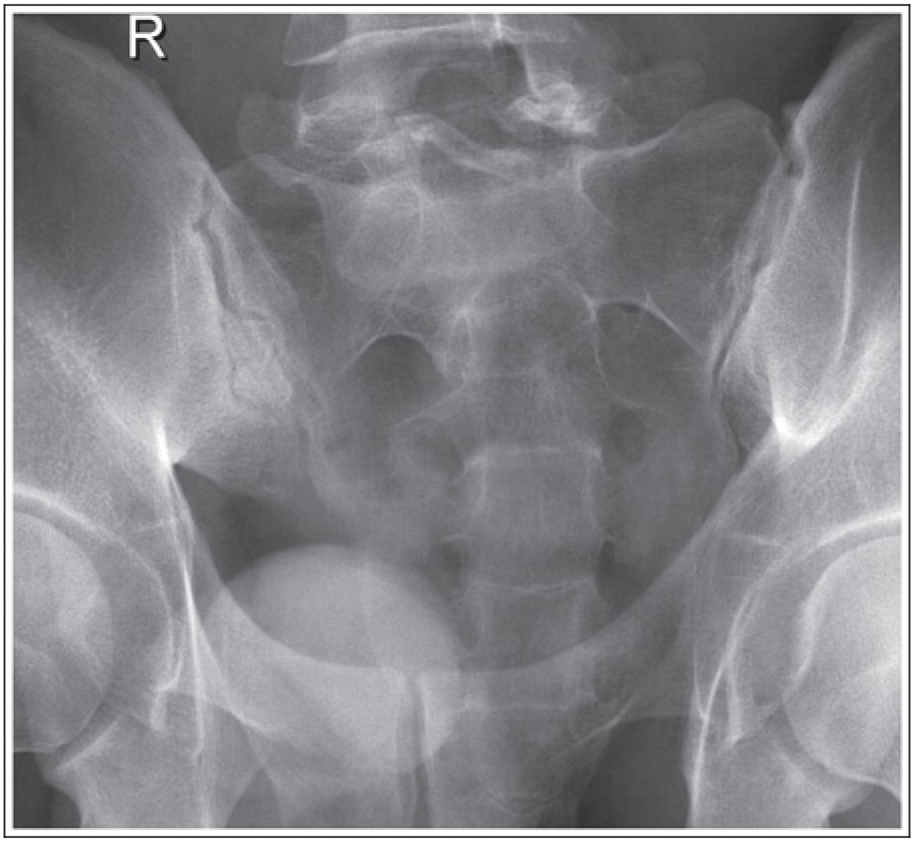


IMAGE 9.5

Analysis

The patient was rotated toward the right side (RPO rotation) and the cephalic CR angulation was excessive.

Correction

Rotate the patient toward the left side until the midcoronal plane is parallel with the IR and slightly decrease the degree of cephalic CR angulation.

Sacrum: Lateral Projection

See **Table 9.7** and **Figs. 9.39** and **9.40**.

Rotation

Because the two sides of the pelvis are mirror images, it is difficult to determine which side of the patient was rotated anteriorly and which posteriorly on a lateral sacral projection with poor positioning. When visible, the femoral heads may be used to determine rotation. The femoral head that is projected more inferiorly and demonstrates the greater magnification is the one situated farther from the IR (**Fig. 9.41**).

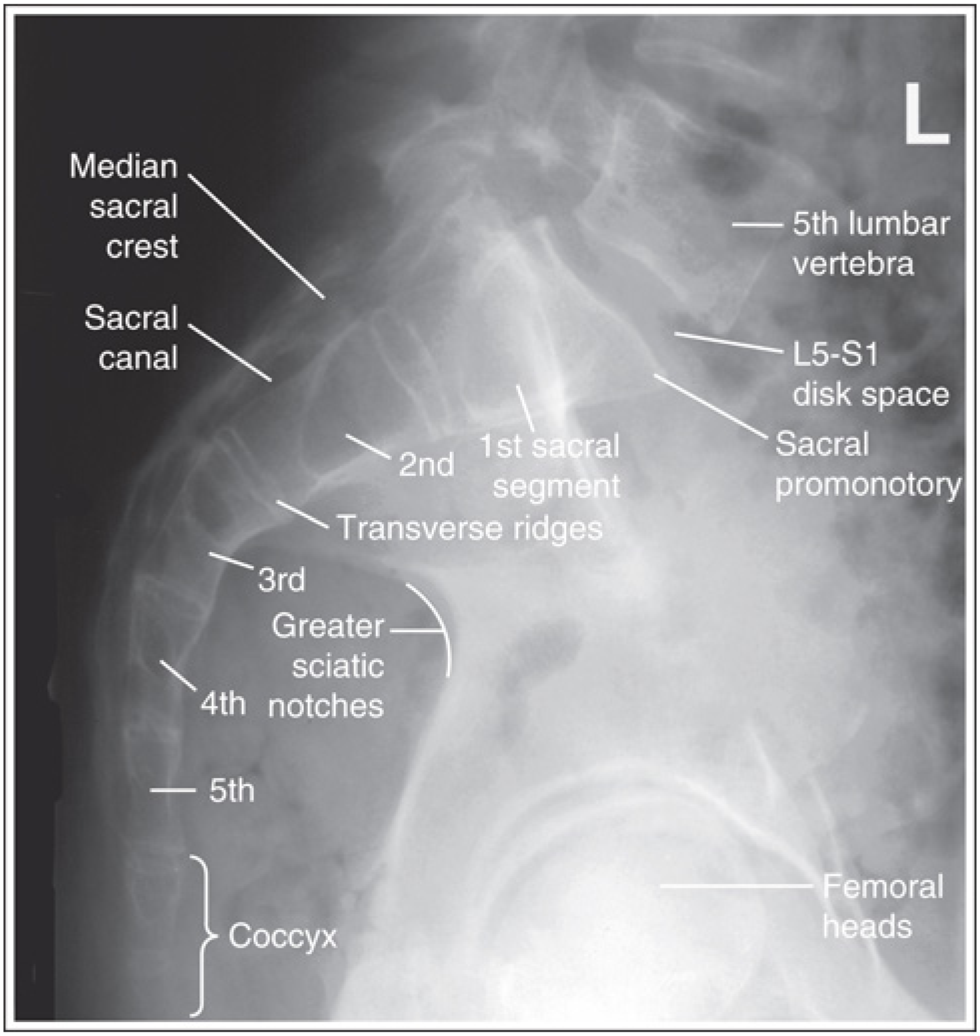


FIGURE 9.39 Lateral sacral projection with accurate positioning.

TABLE 9.7

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

Openness of L5-S1 Disk Space and Sacral Foreshortening

If the lateral vertebral column is allowed to flex laterally, causing it to sag for the lateral sacral projection, the resulting projection demonstrates the greater sciatic notches without superoinferior alignment and a closed L5-S1 disk space (see **Figs. 9.41** and **9.42**) (see discussion in lateral lumbar projection, **Fig. 9.18**). See the discussion in the lateral L5-S1 projection on how to adjust for the sagging vertebral column (see **Figs. 9.28** and **9.31**).

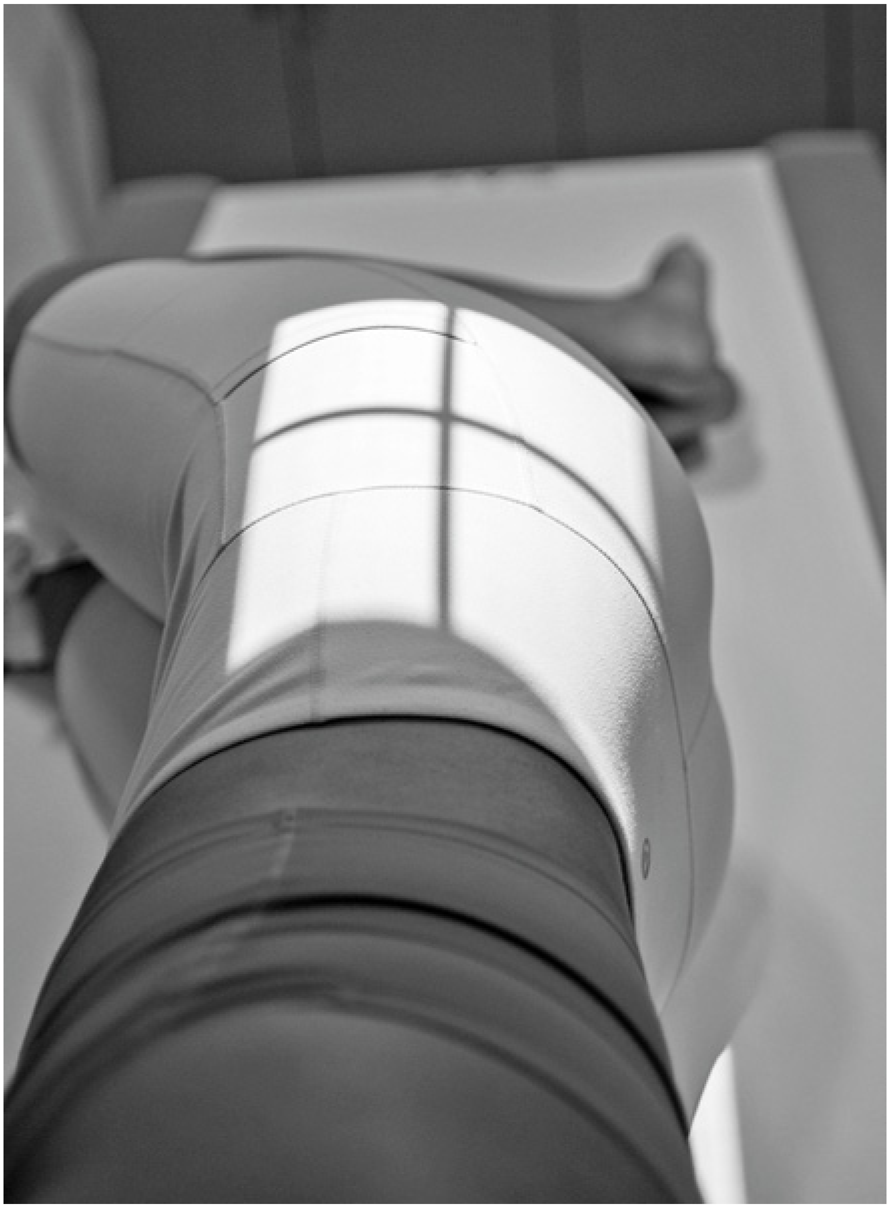


FIGURE 9.40 Proper patient positioning for lateral sacral projection.

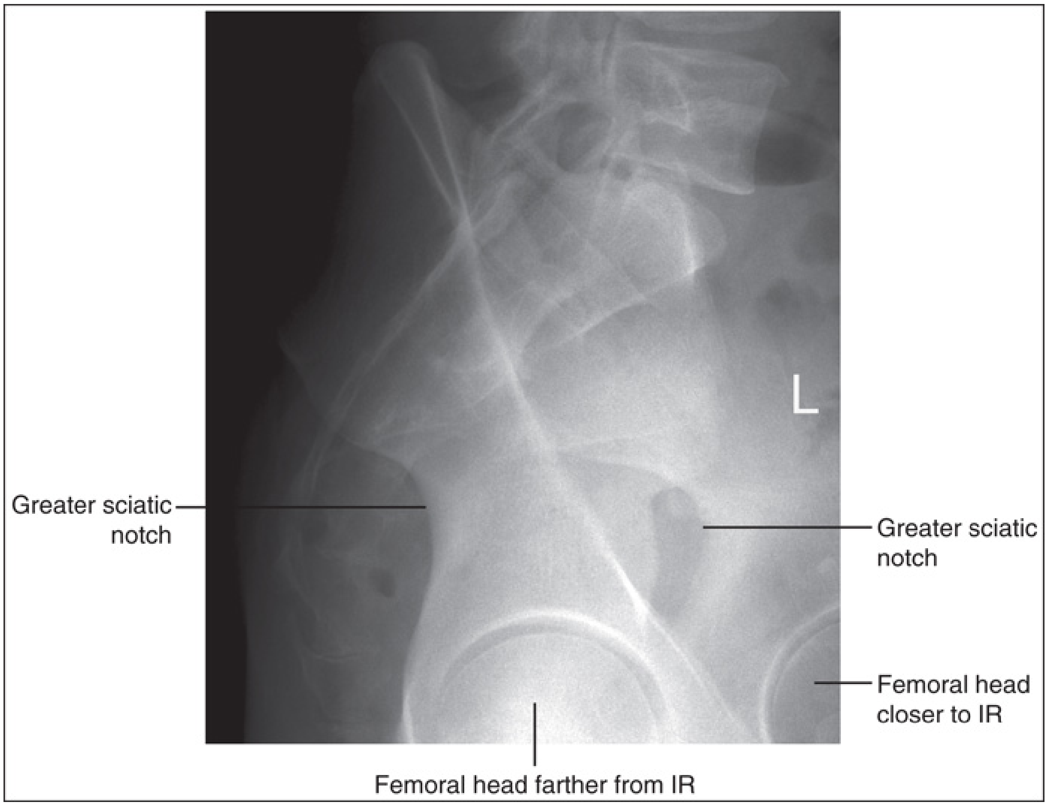


FIGURE 9.41 Lateral sacral projection taken with the right side rotated posteriorly.

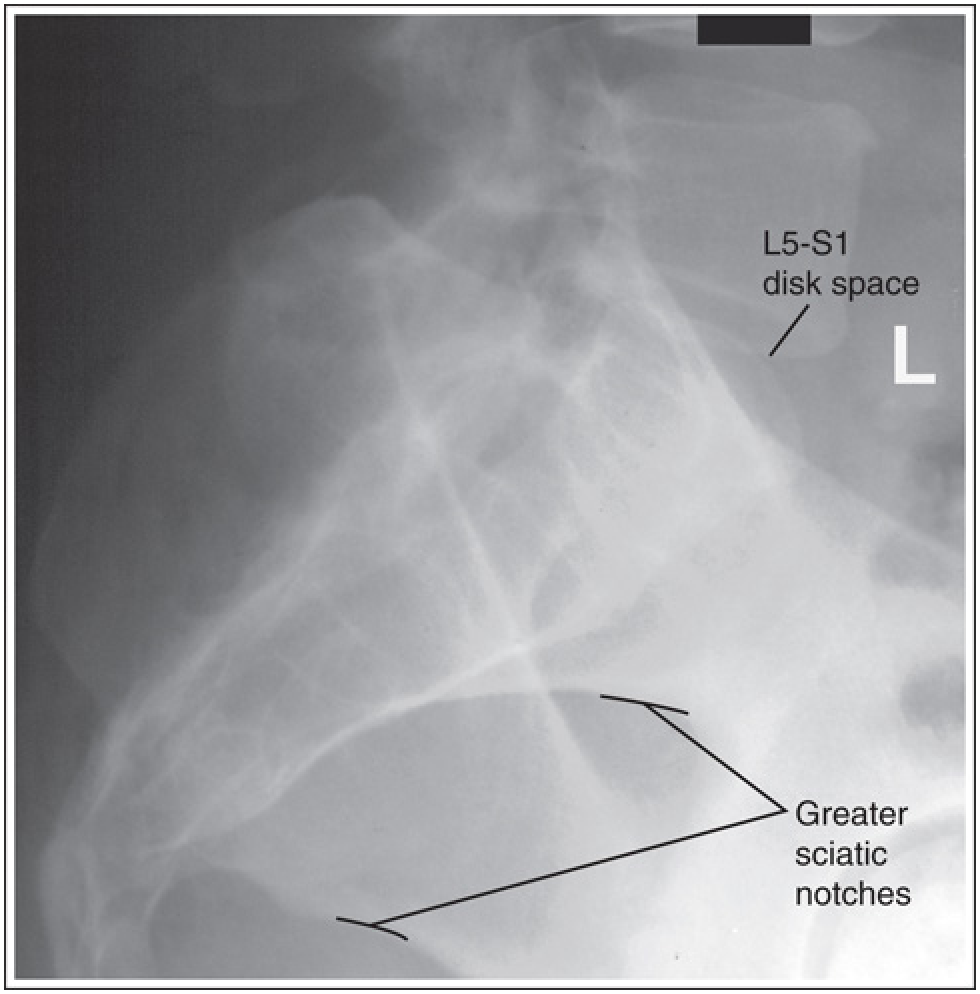


FIGURE 9.42 Lateral sacral projection taken without the vertebral column and sacrum aligned parallel with the IR.

Lateral Sacrum Analysis Practice

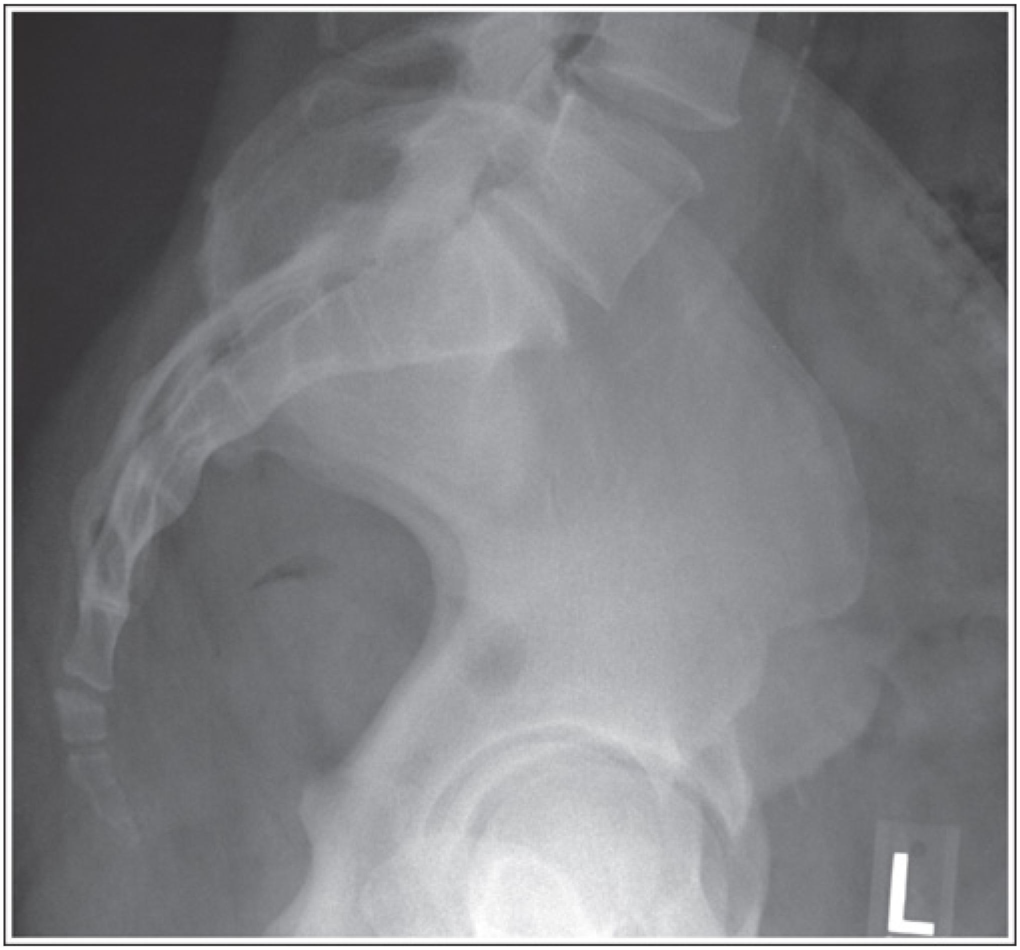


IMAGE 9.6

Analysis

The L5-S1 intervertebral disk space is closed and the L5 vertebral body and sacrum are distorted. The lumbar vertebral column was sagging toward the imaging table.

Correction

Place a radiolucent sponge between the patient's lateral body surface and imaging table to align the vertebral column parallel with the IR or angle the CR caudally until it parallels the interiliac line.

Coccyx: AP Axial Projection

See **Table 9.8** and **Figs. 9.43** and **9.44**.

Emptying Bladder and Rectum

The urinary bladder should be emptied before the procedure. It is also suggested that the colon be free of gas and fecal material. Both procedures will prevent overlap of these materials onto the coccyx, thereby improving its visualization (**Figs. 9.45** and **9.46**).

Rotation

Rotation is detected on an AP coccyx projection by evaluating the alignment of the long axis of the coccyx with the pubis symphysis and by comparing the distances from the coccyx to the lateral walls of the inlet pelvis. If the patient was rotated away from the supine position, the coccyx moves in a direction opposite the direction of the pubis symphysis and is positioned closer to the lateral pelvic wall situated farther from the IR. If the patient was rotated into an LPO position, the coccyx is rotated toward the right side (see **Fig. 9.5**). If the patient was rotated into an RPO position, the coccyx is rotated toward the left side (**Fig. 9.47**).

CR and Coccyx Alignment

When the patient is in an AP projection with the legs extended, the coccyx curves anteriorly and is located beneath the pubis symphysis. To demonstrate the coccyx without foreshortening and without overlap by the pubis symphysis, a 10-degree caudal CR angulation is used. This angle aligns the CR perpendicular to the coccyx and projects the pubis symphysis inferiorly. If the AP projection of the coccyx is taken with an insufficient caudal CR angle, the second and third coccygeal vertebrae are foreshortened and are superimposed by the pubis symphysis (**Fig. 9.48**).

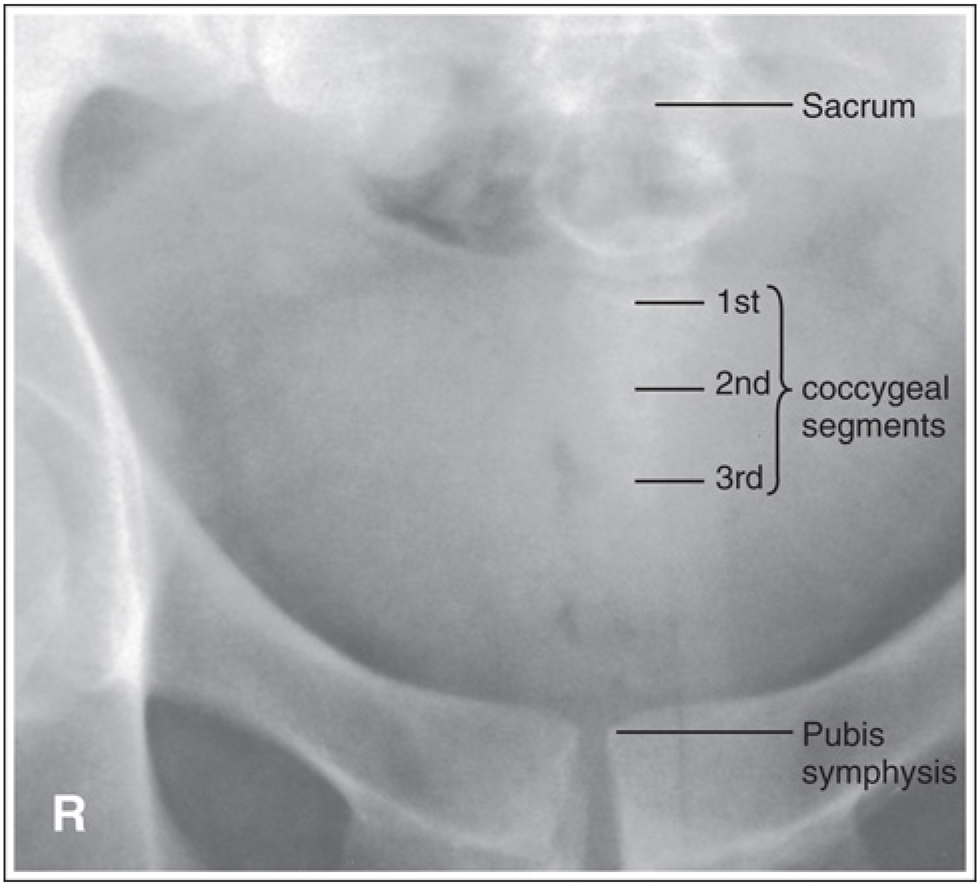


FIGURE 9.43 AP axial coccygeal projection with accurate positioning.

TABLE 9.8

AP, Anteroposterior; *ASIS*, anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

FIGURE 9.44 Proper patient positioning for AP axial coccygeal projection.

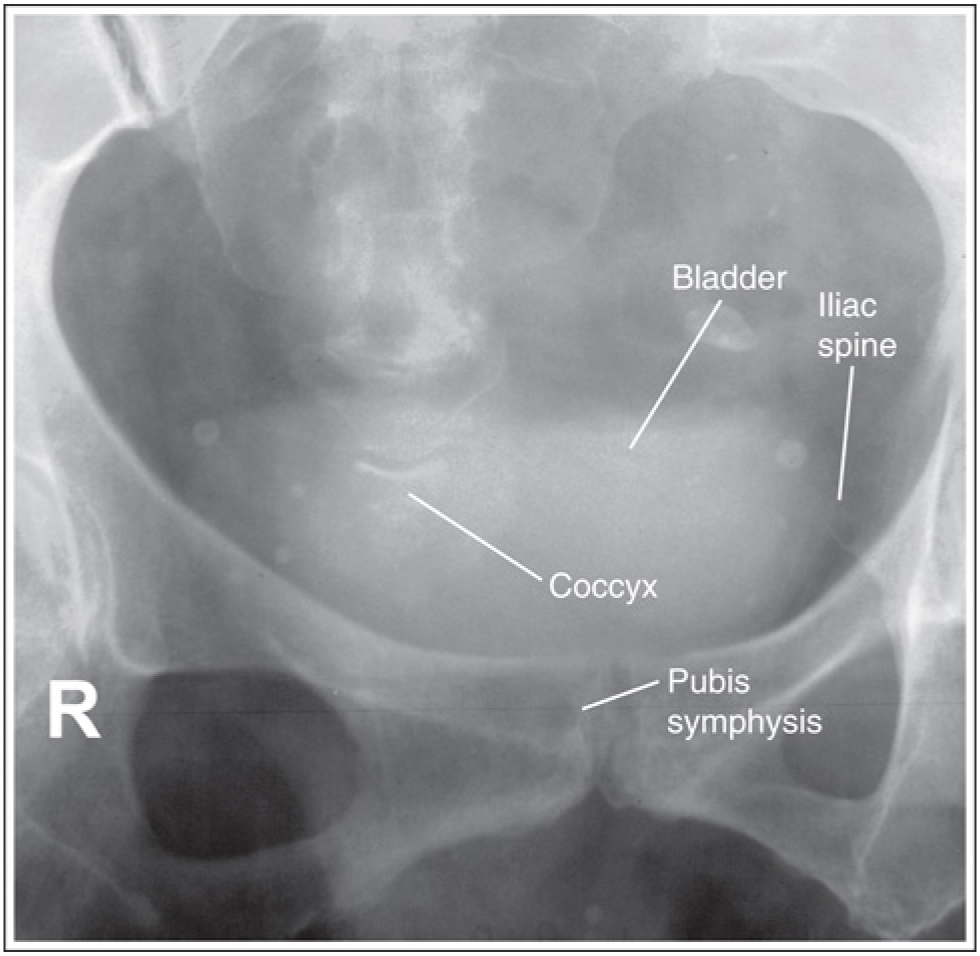


FIGURE 9.45 AP axial coccyx projection taken without the bladder emptied and with the patient rotated onto the left side.

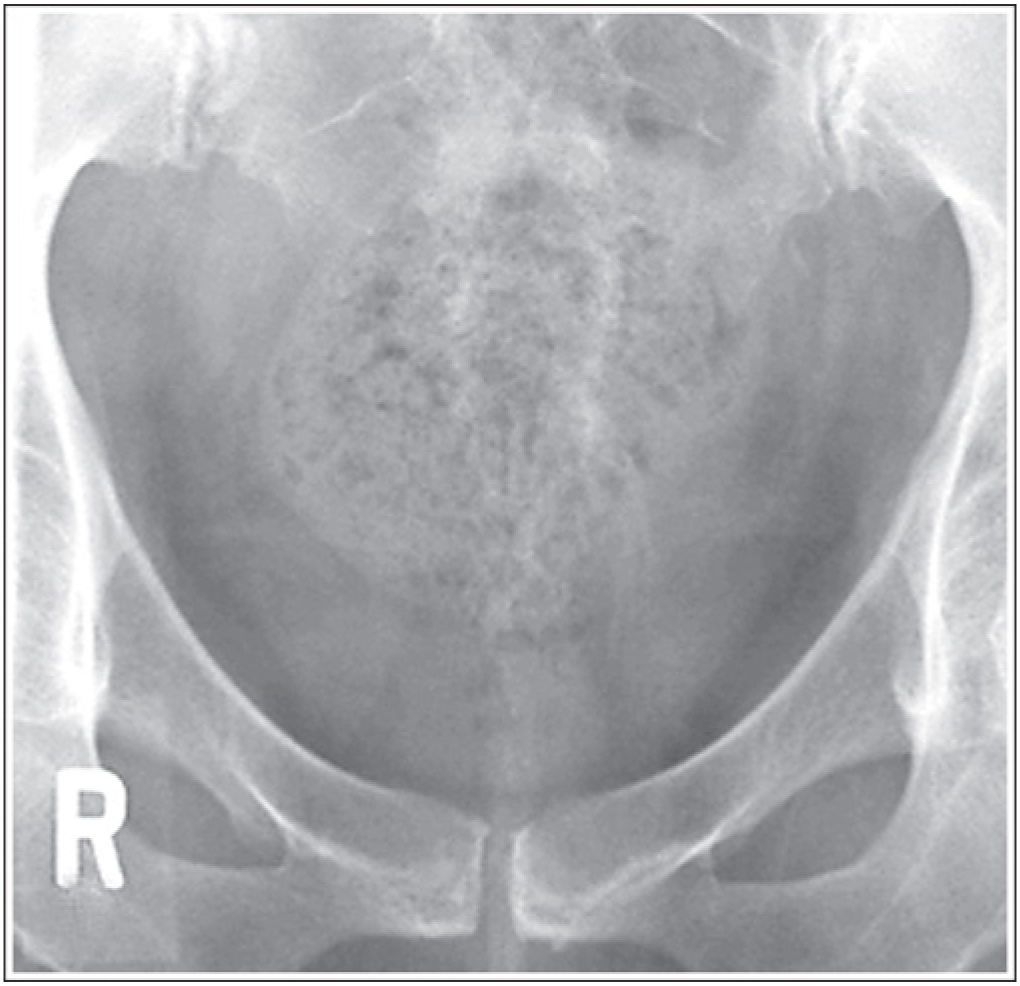


FIGURE 9.46 AP axial coccyx projection demonstrating fecal matter superimposed over the coccyx.

FIGURE 9.47 AP coccyx projection with patient in RPO position.

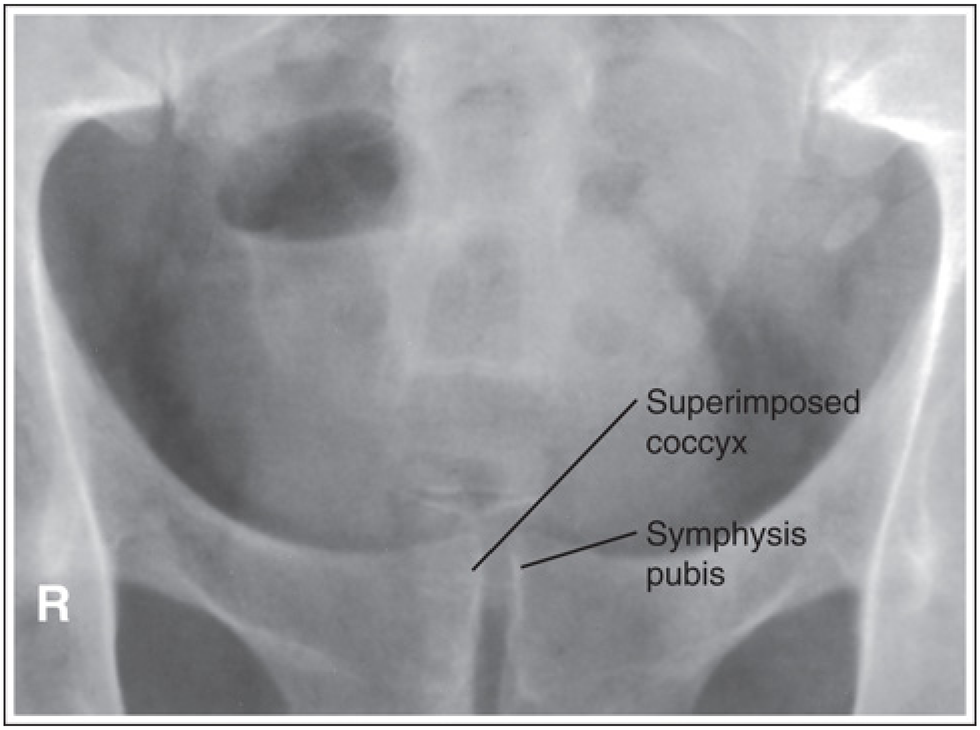


FIGURE 9.48 AP axial coccyx projection demonstrating insufficient caudal CR angulation.

AP Coccyx Analysis Practice

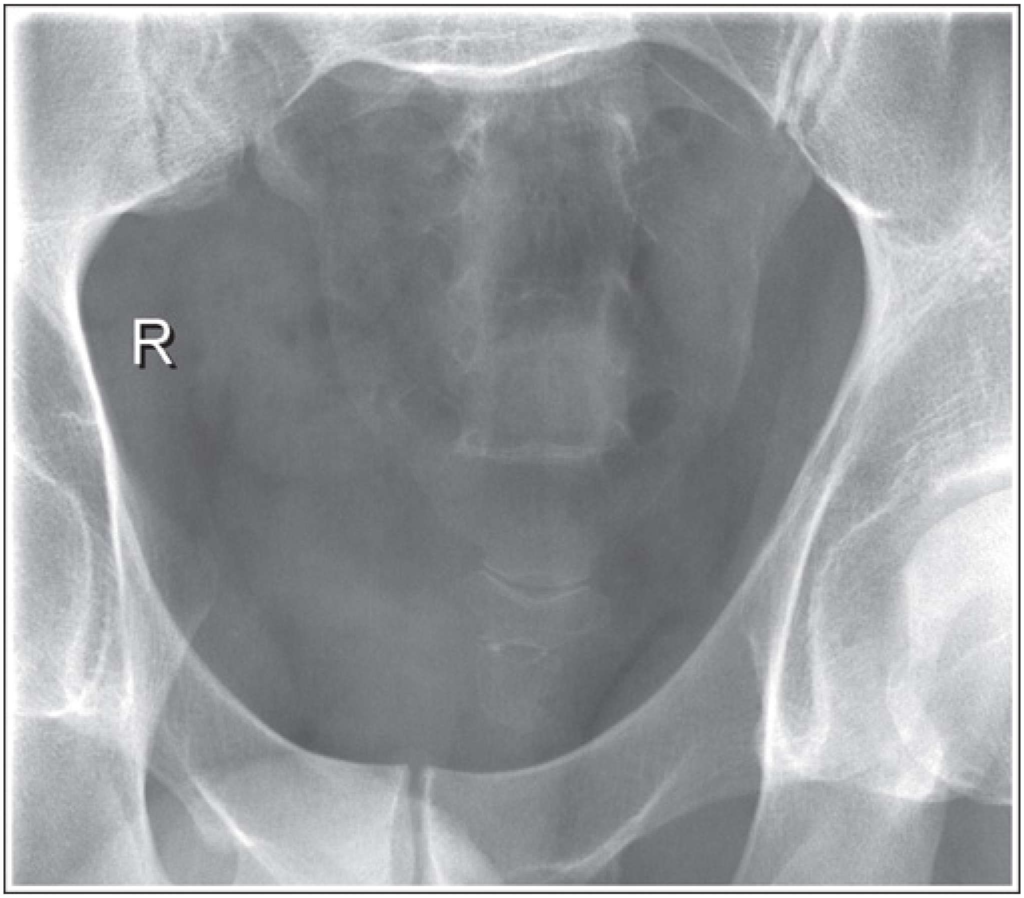


IMAGE 9.7

Analysis

The patient was rotated toward the right side (RPO rotation) and the caudal CR angulation was slightly insufficient.

Correction

Rotate the patient toward the left side until the midcoronal plane is parallel with the IR and slightly increase the degree of caudal CR angulation.

Coccyx: Lateral Projection

See **Table 9.9** and **Figs. 9.49** and **9.50**.

Rotation

Rotation can be detected on a lateral coccyx projection by evaluating the superimposition of the greater sciatic notches. On a nonrotated lateral coccygeal projection, the greater sciatic notches are superimposed. On rotation the greater sciatic notches are not superimposed but are demonstrated one anterior to the other, and the coccyx and posteriorly situated ischium are almost superimposed on slight rotation and truly superimposed on severe rotation (**Fig. 9.51**). Because the two sides of the pelvis are mirror images, it is difficult to determine which side of the patient was rotated anteriorly and which posteriorly on a lateral coccygeal projection with poor positioning. When rotation has occurred, it is most common for the side of the patient situated farther from the IR to have been rotated anteriorly if a sponge was not placed between the knees for support, because of the gravitational forward and downward pull on this side's arm and leg.

Coccyx Foreshortening

If the lateral vertebral column is allowed to flex laterally, causing it to sag for the lateral sacral projection, the resulting projection demonstrates a foreshortened coccyx (see discussion in lateral lumbar projection, **Fig. 9.18**). See the discussion in the lateral L5-S1 projection on how to adjust for the sagging vertebral column (see **Figs. 9.28** and **9.31**).

TABLE 9.9

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor.

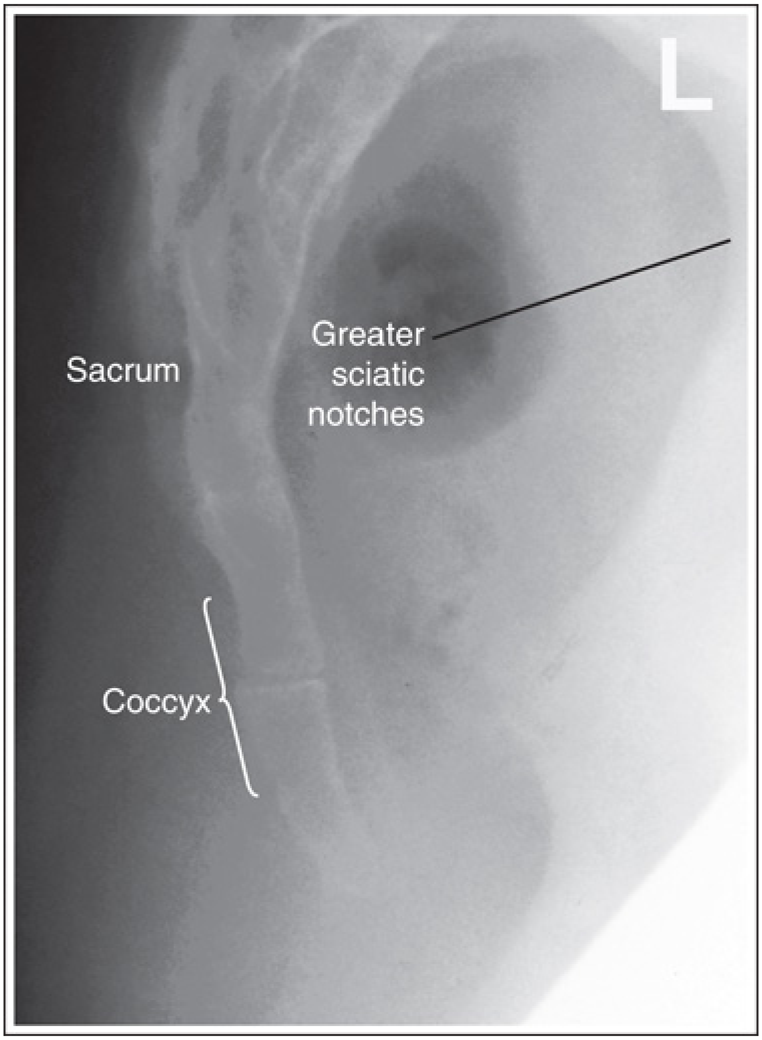


FIGURE 9.49 Lateral coccygeal projection with accurate positioning.

FIGURE 9.50 Proper patient positioning for lateral coccygeal projection.

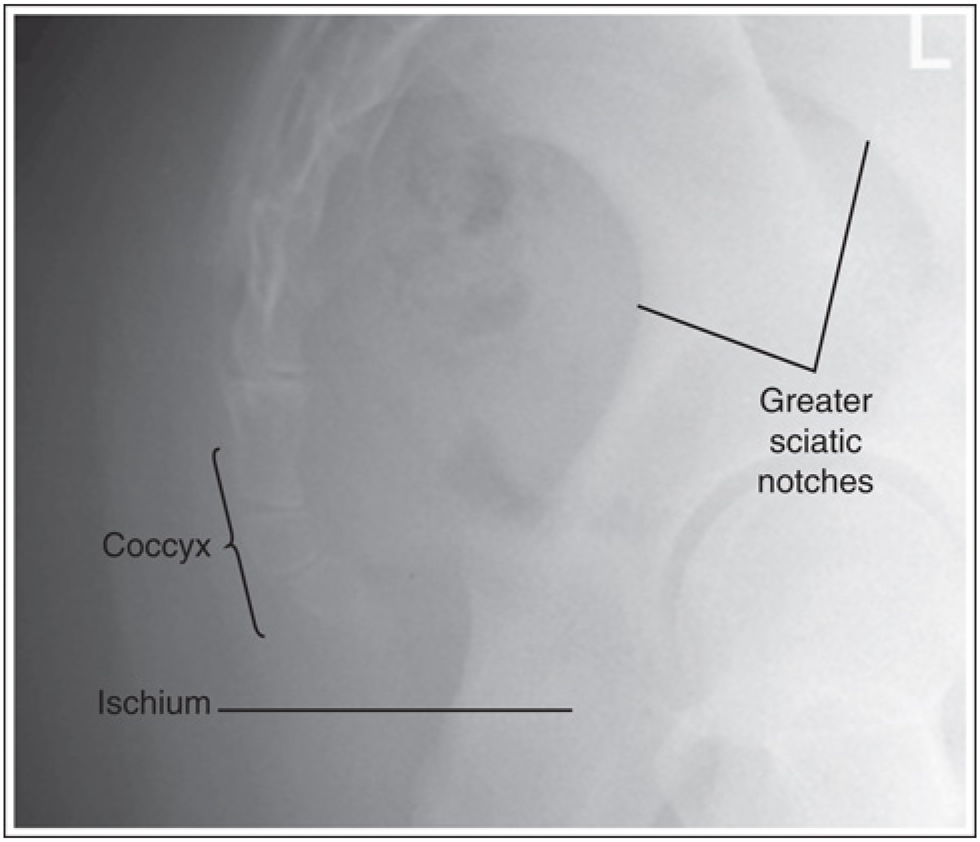


FIGURE 9.51 Lateral coccyx projection taken with rotation.

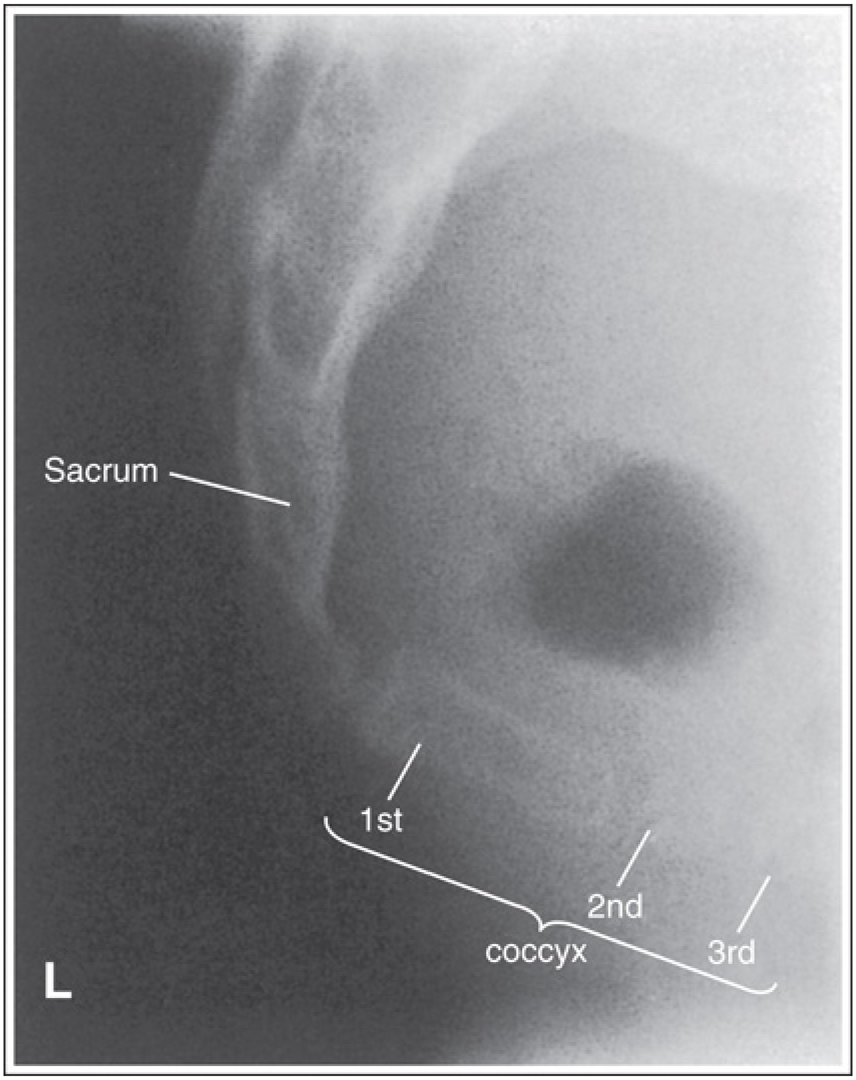


FIGURE 9.52 Lateral coccyx projection taken with excessive collimation.

Collimation

Because tight collimation is essential to obtain optimal recorded detail visibility, collimate longitudinally and transversely to a 4-inch (10-cm) field. The third coccygeal vertebra is situated slightly more anteriorly than the first coccygeal vertebra. With injury, this anterior position may be increased, causing the coccyx to align transversely (**Fig. 9.52**). When this condition is suspected, transverse collimation should not be too tight.

Chapter 10: Image Analysis of the Bony Thorax

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Identify the required anatomy of the bony thorax projections.
- Describe how to properly position the patient, image receptor (IR), and central ray (CR) on the bony thorax projections.
- List the image analysis requirements for the bony thorax projections with accurate positioning and state how to reposition the patient when less than optimal projections are produced.
- Describe how the patient is positioned to achieve homogeneous density on posteroanterior (PA) oblique sternal projections.
- Explain why a 30-inch (76-cm) source–image receptor distance (SID) is used on PA oblique sternal projections.
- Define costal breathing, and discuss the advantages of using it for PA oblique sternal projections.
- Describe how thoracic thickness affects how far the sternum is positioned from the vertebral column when the patient is rotated.
- List ways of reducing the amount of scatter radiation that reaches the IR when the sternum is imaged in the lateral projection.
- Discuss when it is appropriate to take an anteroposterior (AP) projection of the ribs rather than a PA projection and why the AP oblique projection is preferred over the PA oblique projection when the axillary ribs are imaged.

Image Analysis Guidelines

Technical Data

See **Table 10.1** and **Box 10.1**.

Sternum: PA Oblique Projection (RAO Position)

See **Table 10.2** and **Figs. 10.1** and **10.2**.

Homogeneous Sternum Brightness and RAO Positioning

The right AP oblique projection (right anterior oblique [RAO] position) is used to rotate the sternum from beneath the thoracic vertebrae. It is chosen over the left anterior oblique (LAO) position because the RAO position superimposes the heart shadow over the sternum (**Fig. 10.3**). Because the air-filled lungs and heart shadow have different atomic densities, they demonstrate distinctly different degrees of brightness on the resulting projection using the same exposure factors. The air-filled lungs demonstrate less brightness than the heart shadow. Positioning the sternum beneath the heart shadow ensures homogeneous brightness across the entire sternum. Any portion of the sternum positioned outside the heart shadow demonstrates less brightness than the portion positioned within the heart shadow and is more difficult to see (**Fig. 10.4**).

Excessive Chest and Sternum Obliquity

Rotating the chest and sternum until the midcoronal plane is angled 15 to 20 degrees with the image receptor (IR) is enough obliquity to position the sternum away from the vertebral column and beneath the heart shadow. To determine the exact obliquity needed to rotate the sternum away from the thoracic vertebral column on a prone patient, place the fingertips of one hand on the right sternoclavicular (SC) joint and the fingertips of the other hand on the spinous processes of the upper thoracic vertebrae. Rotate the

chest until your fingers on the SC joints are positioned just to the left of the fingers on the spinous processes.

If the degree of chest and sternum obliquity was more than needed, the sternum moves to the left of the heart shadow and will demonstrate excessive transverse foreshortening (see **Fig. 10.4**).

Insufficient Chest and Sternum Obliquity

If the degree of chest and sternum obliquity was less than needed to move the sternum from beneath the vertebral column, portions of the right SC joint, manubrium, and sternal body are positioned beneath the vertebral column (see **Fig. 10.5**).

Blurring Overlying Sternal Structures

In the PA oblique projection, the sternum has many overlying structures—the posterior ribs, lung markings, heart shadow, and left inferior scapula. Specific positioning techniques should be followed to show a sharply defined sternum while magnifying and blurring these overlying structures. The SID recommended for the PA oblique sternum varies among positioning textbooks. It ranges from 30 to 40 inches (76 to 100 cm). A short (30-inch) SID provides increased magnification and blurring of the posterior ribs and left scapula but also results in a higher patient entrance skin dosage. Facility protocol dictates the SID that is used. Using a breathing technique, which requires a long exposure time (2 to 3 seconds) and requires the patient to breathe shallowly (costal breathing) during the exposure, forces upward and outward and downward and inward movements of the ribs and lungs, thus blurring the posterior ribs and lung markings on the projection. Deep breathing requires movement (elevation) of the sternum to provide deep lung expansion and should be avoided during breathing technique because this sternal motion would blur the

sternum on the projection (**Fig. 10.6**). If breathing technique is not possible, suspend respiration on expiration. When nonbreathing technique is used the details and cortical outlines of the posterior ribs, left scapula, and lung markings are sharply defined, and the increased recorded detail obscures the details of the sternum (see **Figs. 10.4** and **10.6**).

TABLE 10.1

AEC, Automatic exposure control; *AP*, anteroposterior; *PA*, posterioanterior; *SID*, source–image receptor distance.

Box 10.1 Sternum and Ribs Guidelines

VOI, Values of interest.

- The facility's identification requirements are visible.
- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomic structures are sharply defined.
- Contrast resolution is adequate to demonstrate the surrounding soft tissue, bony trabecular patterns, and cortical outlines.
- No quantum mottle or saturation is present.
- Scattered radiation has been kept to a minimum.

• There is no evidence of removable artifacts.

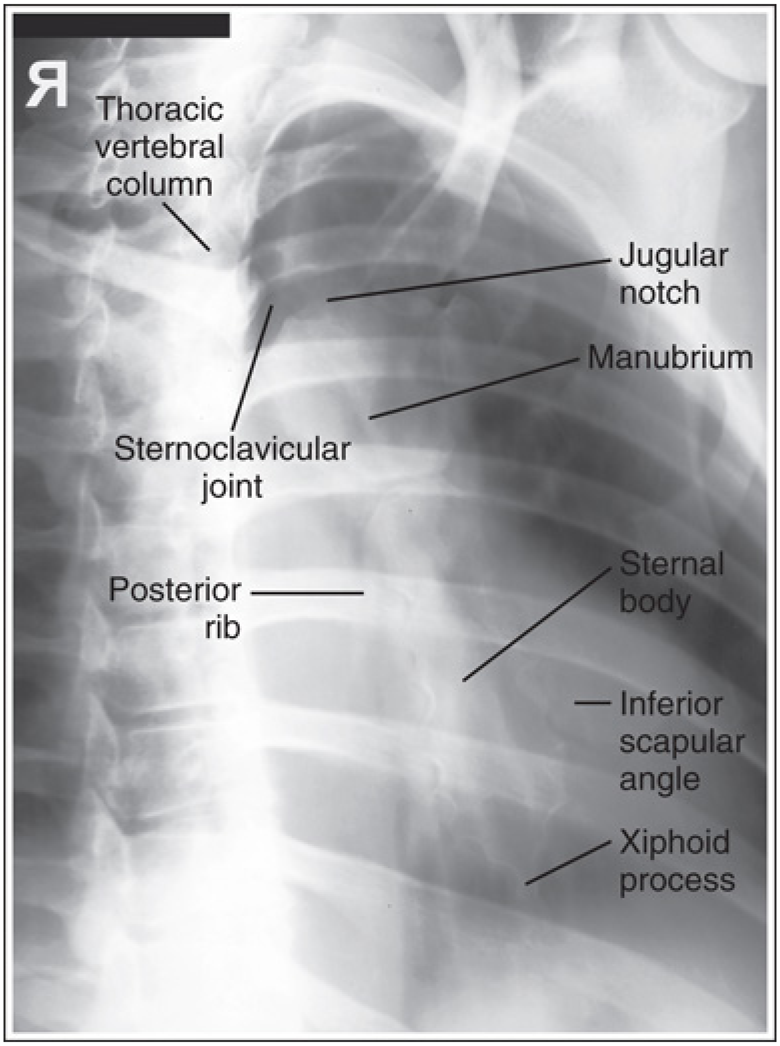


FIGURE 10.1 PA oblique sternum projection (RAO position) with accurate positioning.

TABLE 10.2

CR, Central ray; *IR*, image receptor; *PA*, posterioanterior; *SC*, sternoclavicular; *SID*, source–image receptor distance.

FIGURE 10.2 Proper patient positioning for PA oblique sternum projection (RAO position).

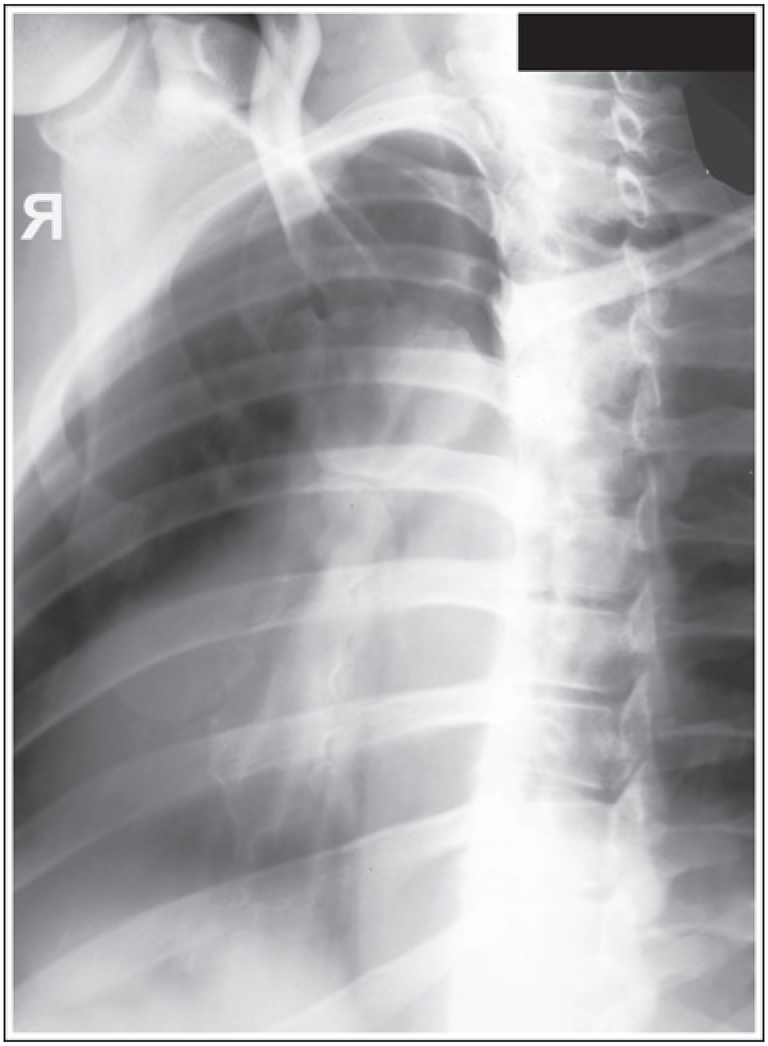


FIGURE 10.3 PA oblique sternal projection taken with the patient in an LAO position.

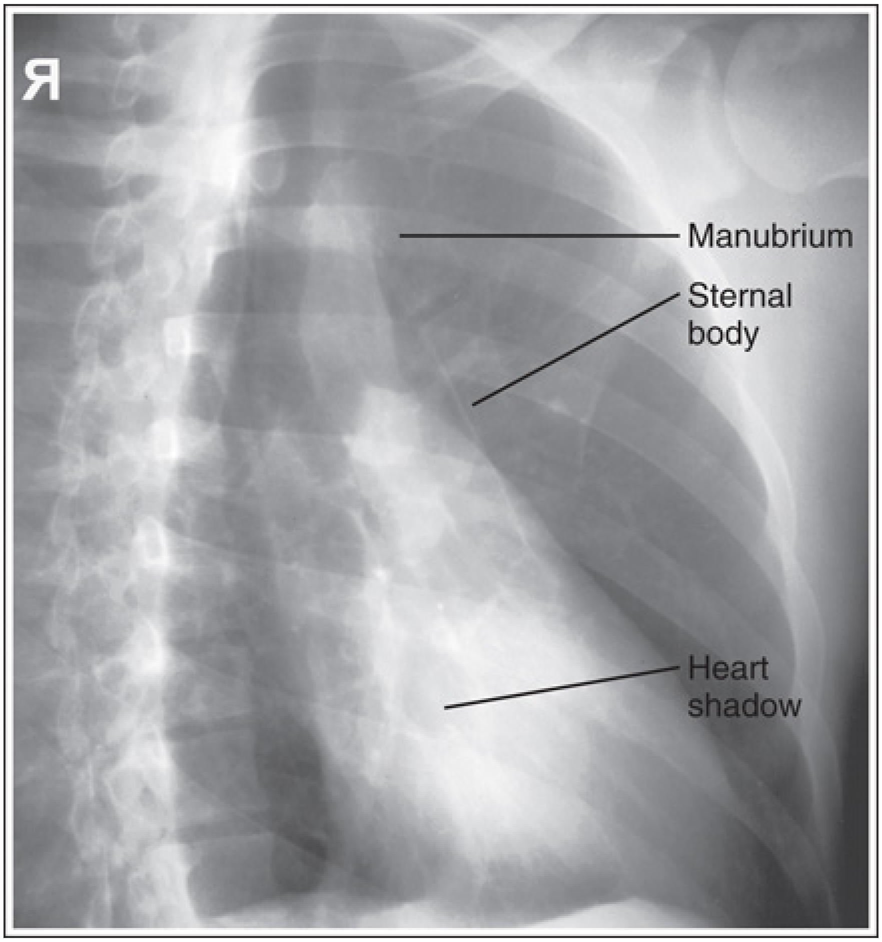


FIGURE 10.4 PA oblique sternum projection taken with excessive patient obliquity and without using breathing technique.

Field Size

The field size used for a PA oblique sternum projection depends on the age and gender of the patient. The adult male sternum is approximately 7 inches (18 cm) long, but the female sternum is considerably shorter. A 10 × 12 inch (24 × 30 cm) field size should sufficiently accommodate male and female adult patients. Because chest depth from the thoracic vertebrae to the manubrium is less than from the thoracic vertebrae to the xiphoid process, the manubrium remains closer to the thoracic vertebrae than the xiphoid

process when the chest is rotated. The sternum, then, is not aligned with the longitudinal plane but is slightly tilted with it. Because of this sternal tilt, the transverse collimation should be confined to the thoracic spinous processes and the left inferior angle of the scapula.

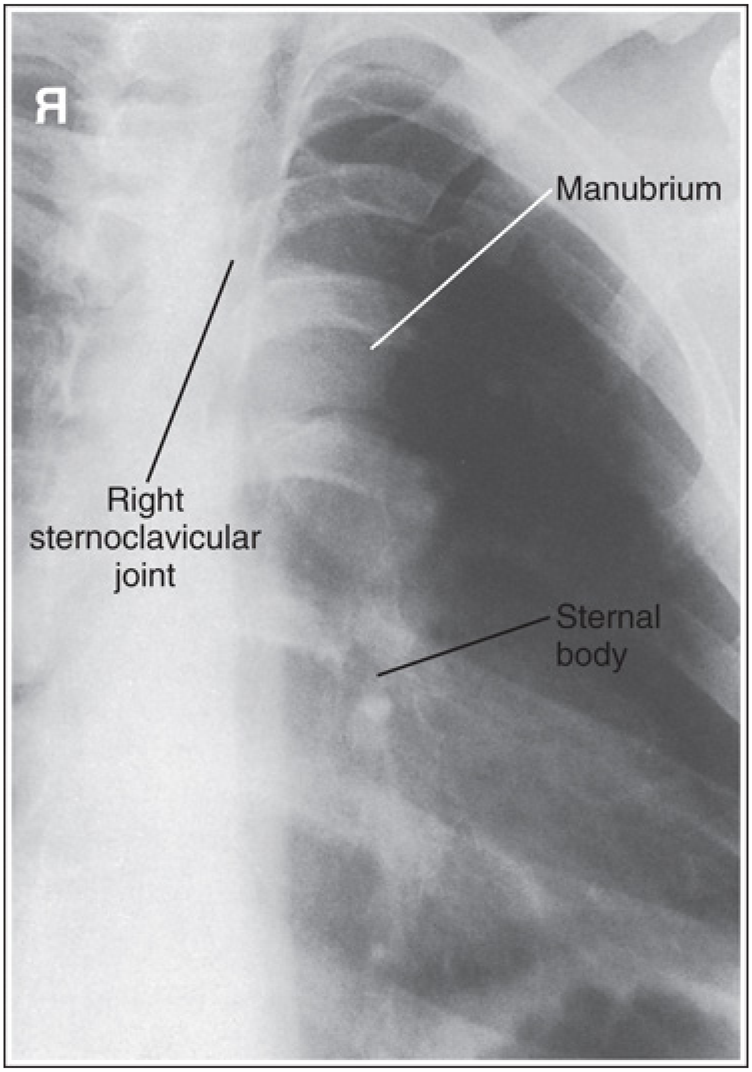


FIGURE 10.5 PA oblique sternal projection taken with insufficient patient obliquity.

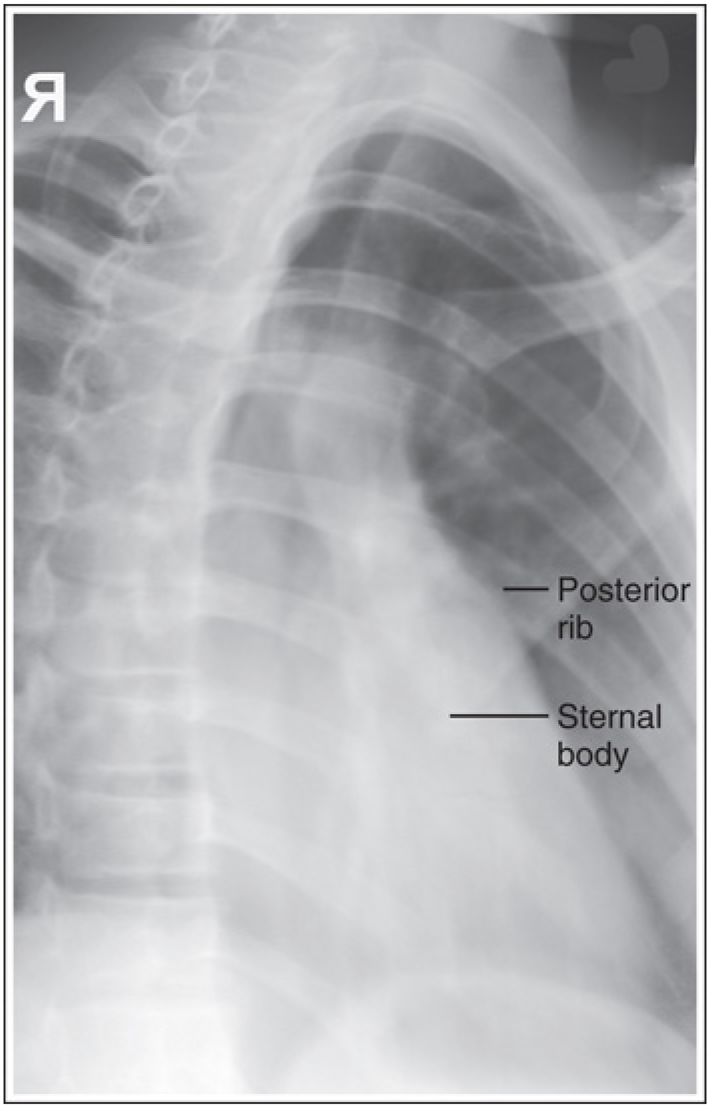


FIGURE 10.6 PA oblique sternum projection taken with the patient breathing deeply instead of shallowly, causing the sternum to move and blur.

PA Oblique Sternum Projection Analysis Practice

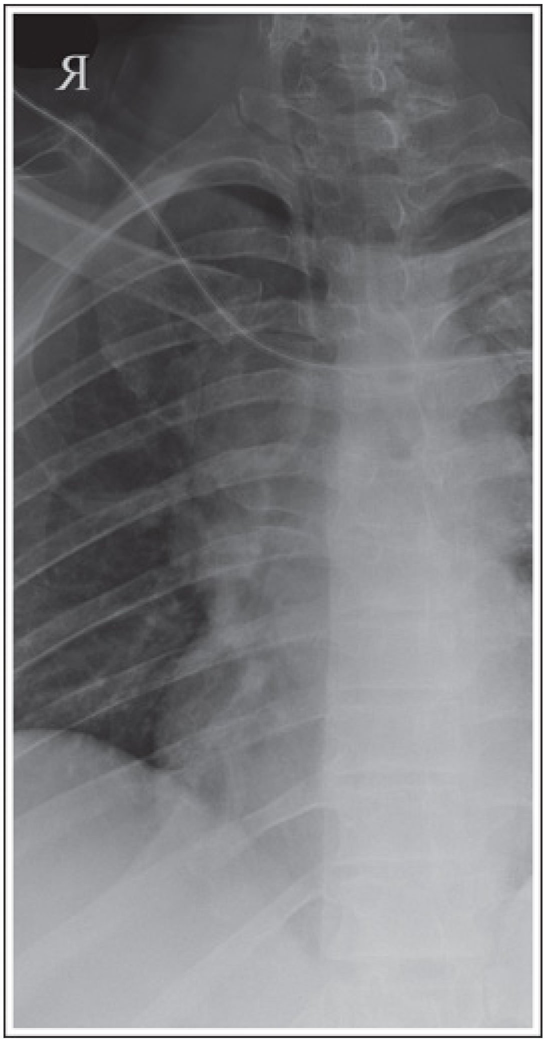


IMAGE 10.1

Analysis

The sternum was not positioned below the heart shadow. The patient was placed in an LAO position instead of a RAO position.

Correction

Place the patient in an RAO position.

Sternum: Lateral Projection

See **Table 10.3** and **Figs. 10.7** and **10.8**.

Positioning for Homogeneous Brightness

Homogeneous brightness over the entire sternum region is difficult to obtain because the lower sternum is superimposed by the pectoral muscles or by the female breast tissue, whereas the upper sternum is free of this superimposition. The amount of brightness difference between the two halves of the sternum depends on the development of the pectoral muscles and the amount of female breast tissue. Increased thickness of either tissue requires an increase in exposure to demonstrate the sternum through them. This increase may overexpose the upper sternum region on the projection, requiring an additional projection to be taken with a lower exposure so the entire sternum can be demonstrated (**Fig. 10.9**).

Rotation

Rotation is effectively detected on a lateral sternum projection by evaluating the degree of anterior rib and sternal superimposition. If a lateral sternum projection demonstrates rotation, the right and left anterior ribs are not superimposed; one side is positioned anterior to the sternum and the other side is positioned posterior to the sternum. Determine how to reposition after obtaining a rotated lateral sternal projection by using the heart shadow to identify the right and left anterior ribs. Because the heart shadow is located in the left chest cavity and extends anteroinferiorly, outlining the superior border of the heart shadow enables recognition of the left side of the chest. If the left lung and ribs were positioned anterior to the sternum, as shown in **Fig. 10.10**, the outline of the superior heart shadow

continues beyond the sternum and into the anteriorly located lung (**Fig. 10.11**).

TABLE 10.3

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor; *SID*, source–image receptor distance.

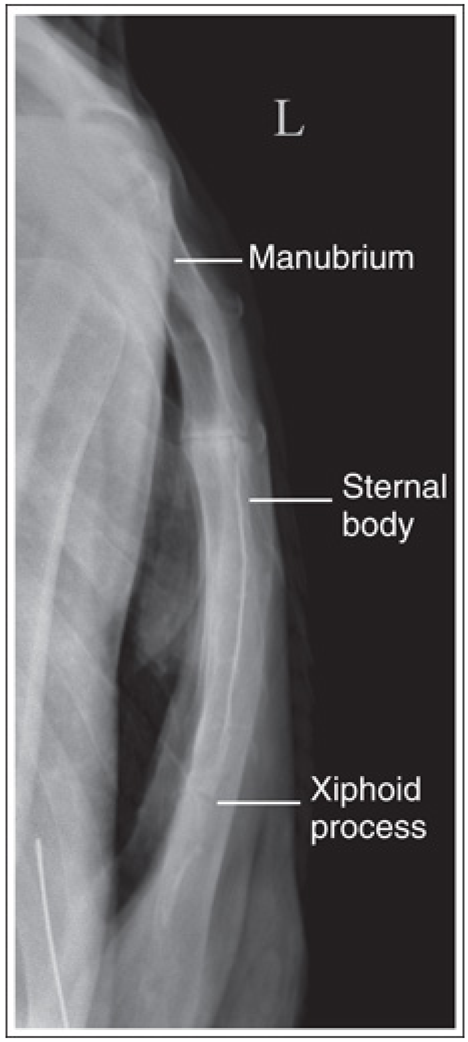


FIGURE 10.7 Lateral sternum projection with accurate positioning.

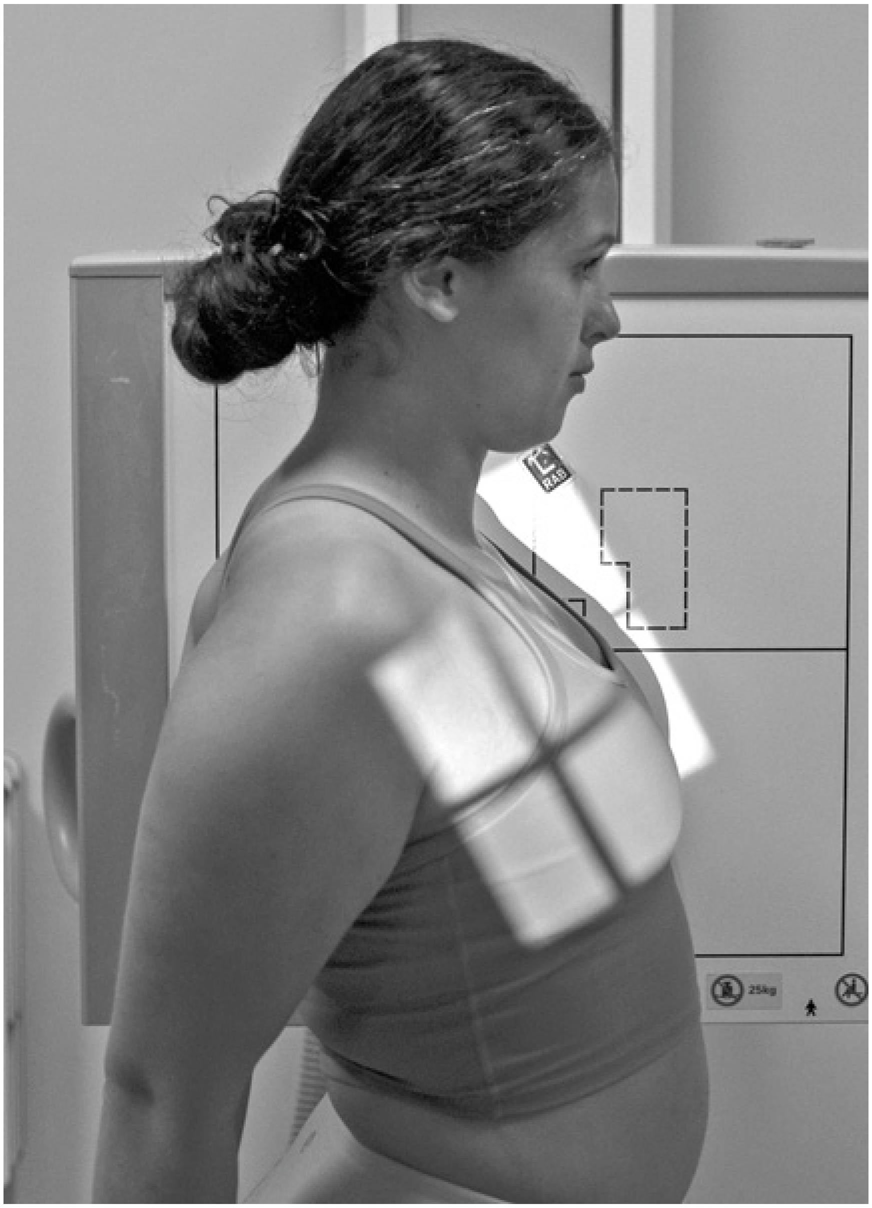


FIGURE 10.8 Proper patient positioning for lateral sternum projection.

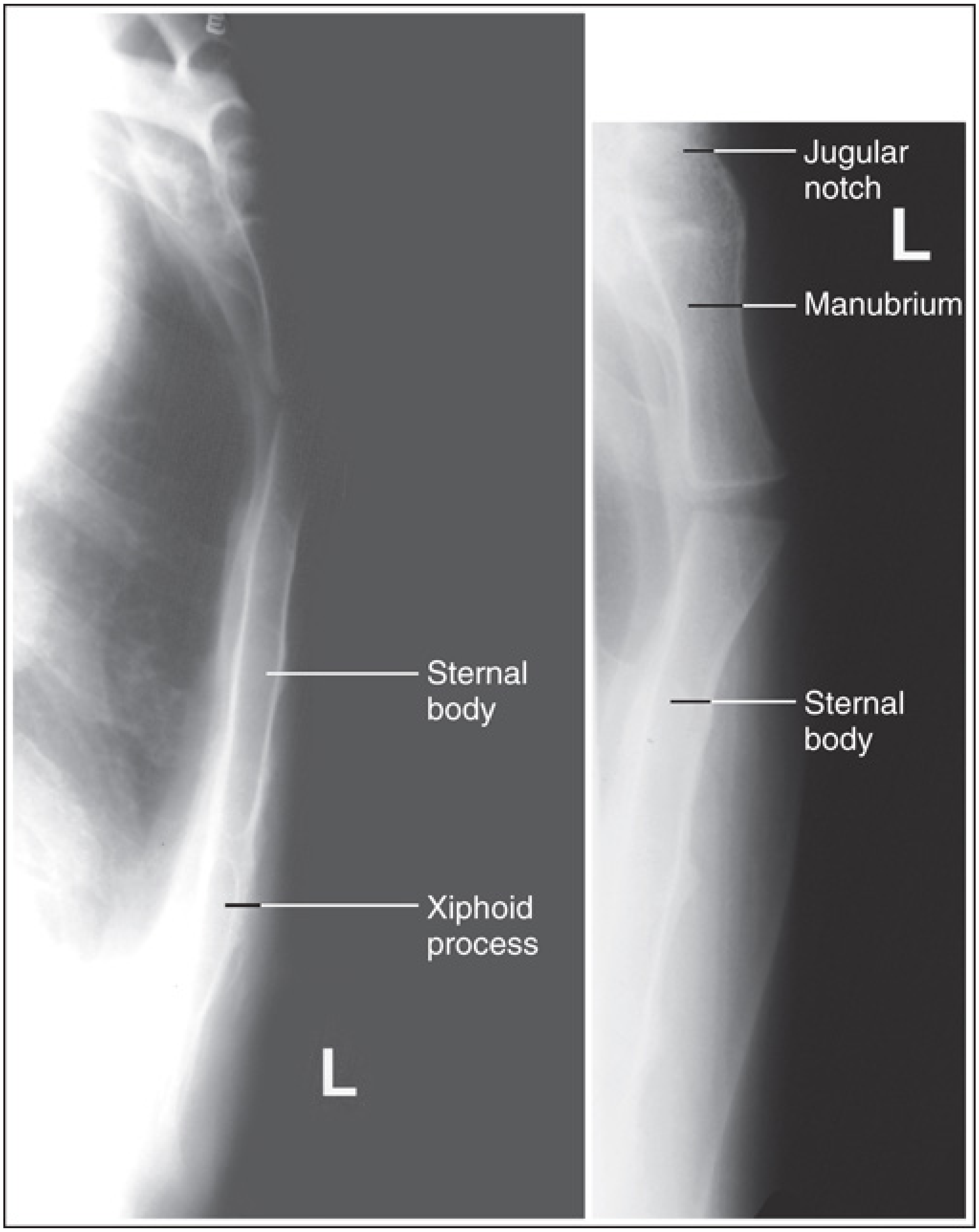


FIGURE 10.9 Lateral sternum projection of superior and inferior sternum with accurate positioning.

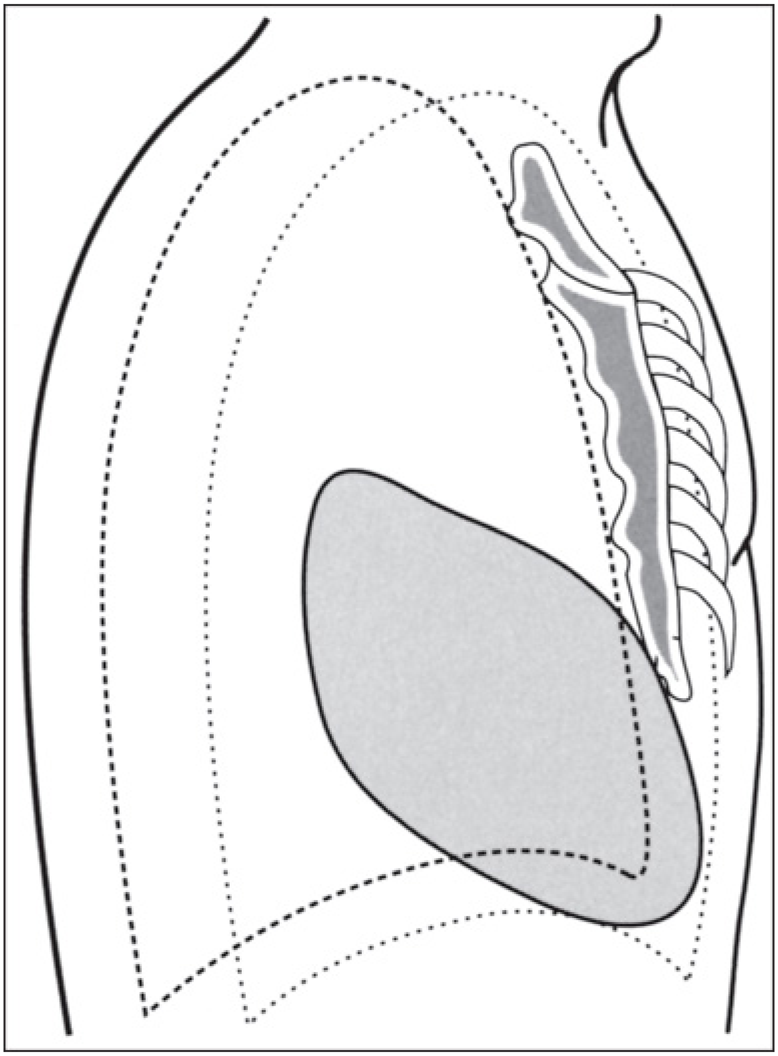


FIGURE 10.10 Rotation—left lung anterior.

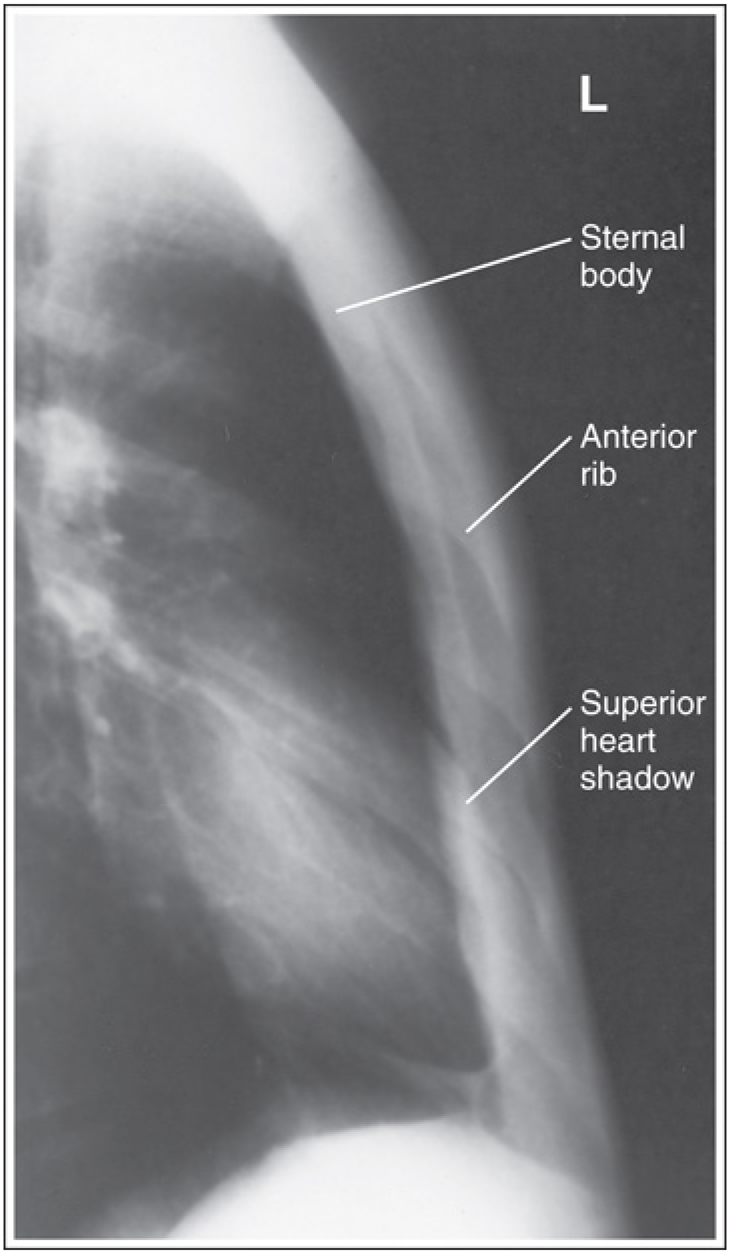


FIGURE 10.11 Lateral sternal projection taken with the left thorax rotated anteriorly.

If the right lung and ribs were positioned anterior to the sternum, as shown in **Fig. 10.12**, the superior heart shadow does not continue into the anteriorly situated lung, but ends at the sternum (**Fig. 10.13**). Once the right and left sides of the chest have been identified, reposition the patient by

rotating the thorax. If the left lung and ribs were anteriorly positioned, rotate the left thorax posteriorly. If the right lung and ribs were anteriorly positioned, rotate the right thorax posteriorly.

Kyphotic Patient

Due to the more anterior location of the shoulders on a kyphotic patient, the patient may not be able to retract the shoulders enough to prevent them from superimposing the manubrium (**Fig. 10.14**).

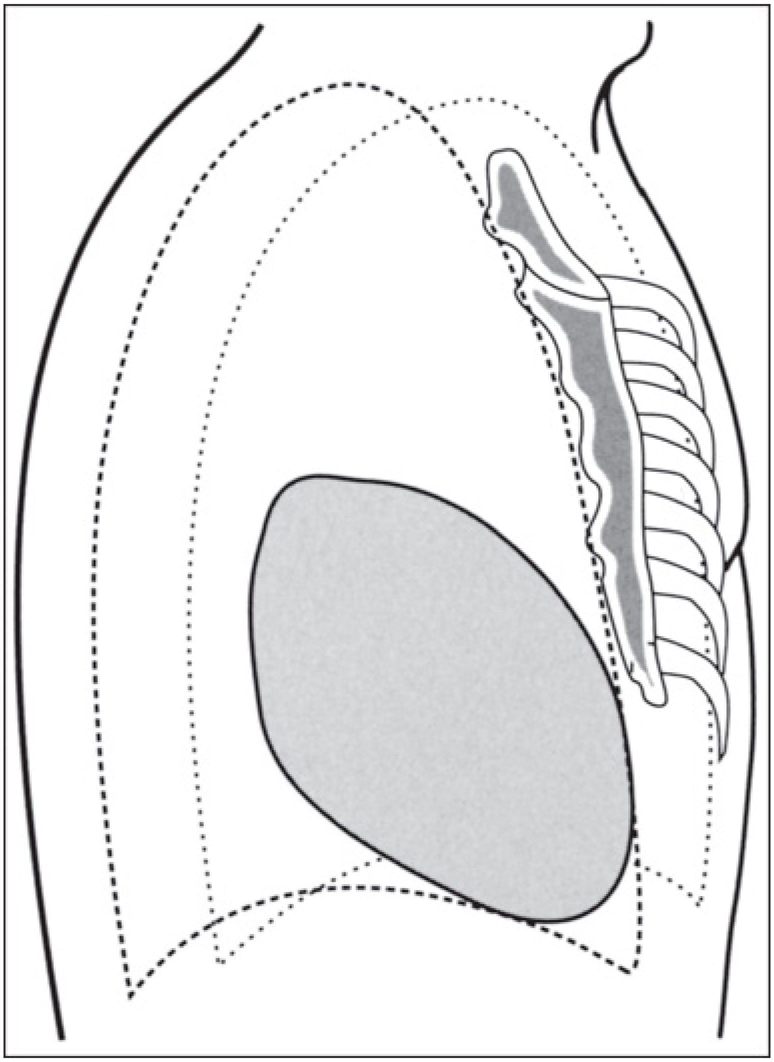


FIGURE 10.12 Rotation—right lung anterior.

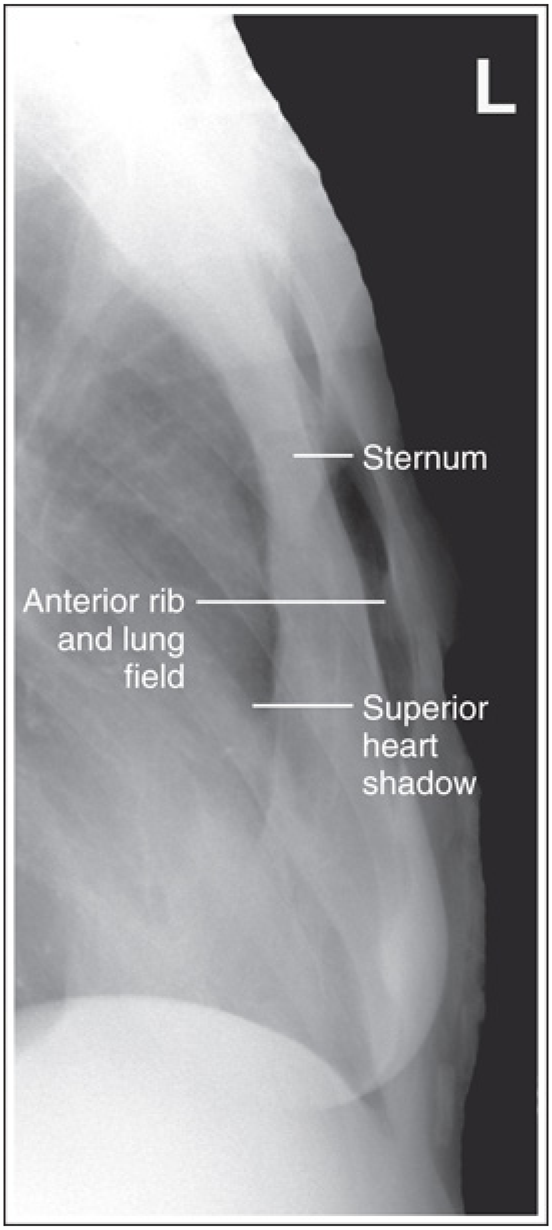


FIGURE 10.13 Lateral sternal projection taken with the right thorax rotated anteriorly.

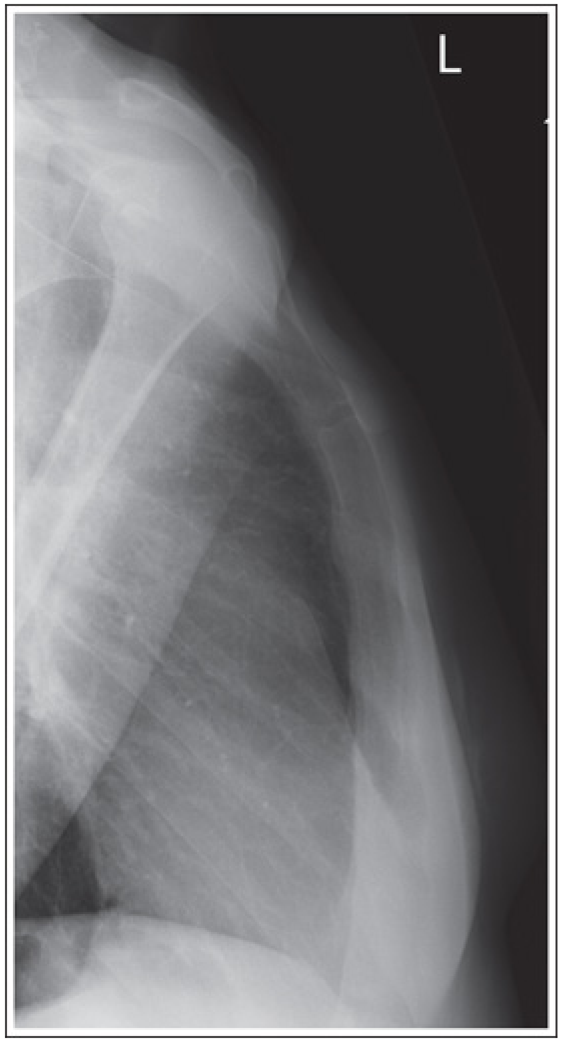


FIGURE 10.14 Lateral sternum projection obtained on a kyphotic patient.

Sternoclavicular (SC) Articulations: PA Projection

See **Table 10.4** and **Figs. 10.15** and **10.16**.

Torso Rotation

Upon rotation the side of the patient that is placed closest to the IR will demonstrate increased superimposition of the medial clavicle (**Fig. 10.17**)

and the side positioned farther from the IR will demonstrate the SC articulation.

TABLE 10.4

ASIS, Anterior superior iliac spine; *CR*, central ray; *IR*, image receptor; *PA*, posteroanterior.

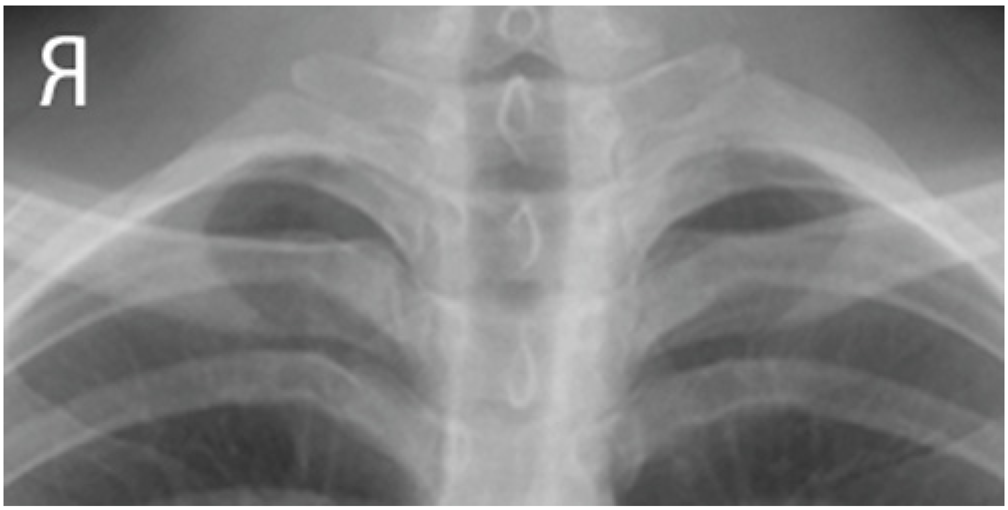


FIGURE 10.15 PA sternoclavicular articulation projection with accurate positioning.

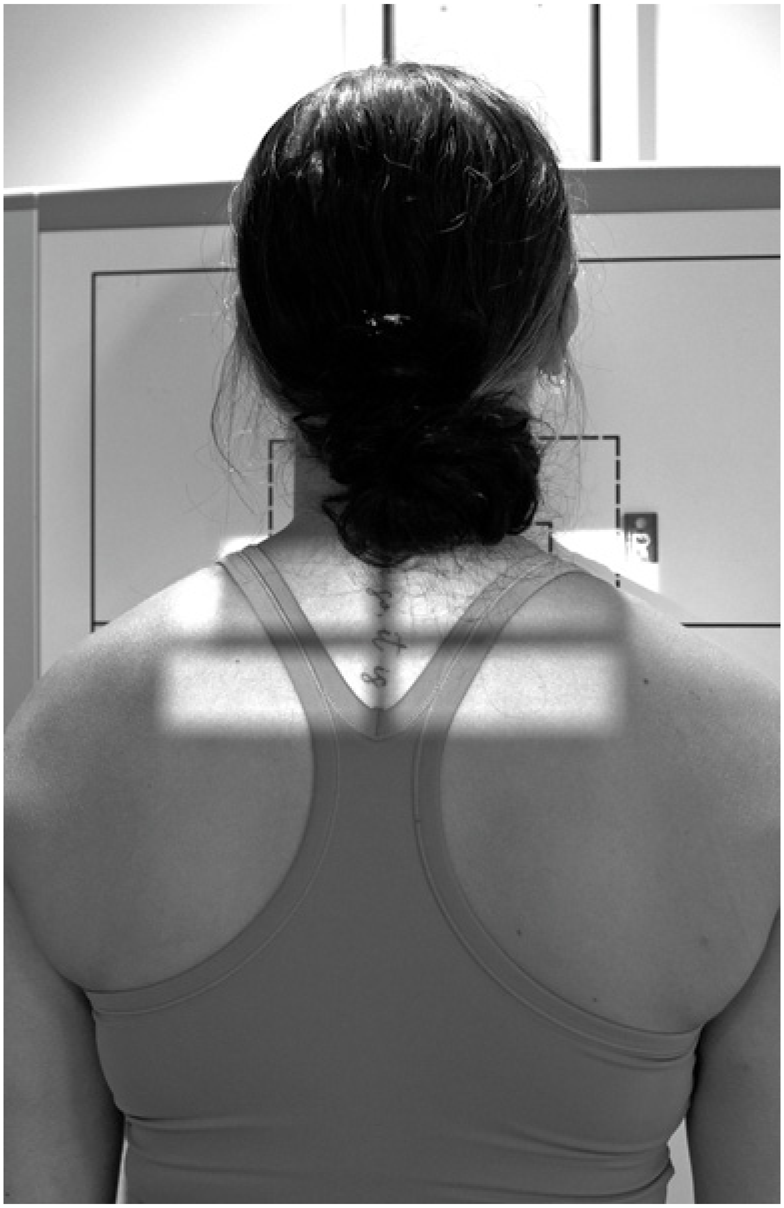


FIGURE 10.16 Proper patient positioning for PA sternoclavicular articulation projection.

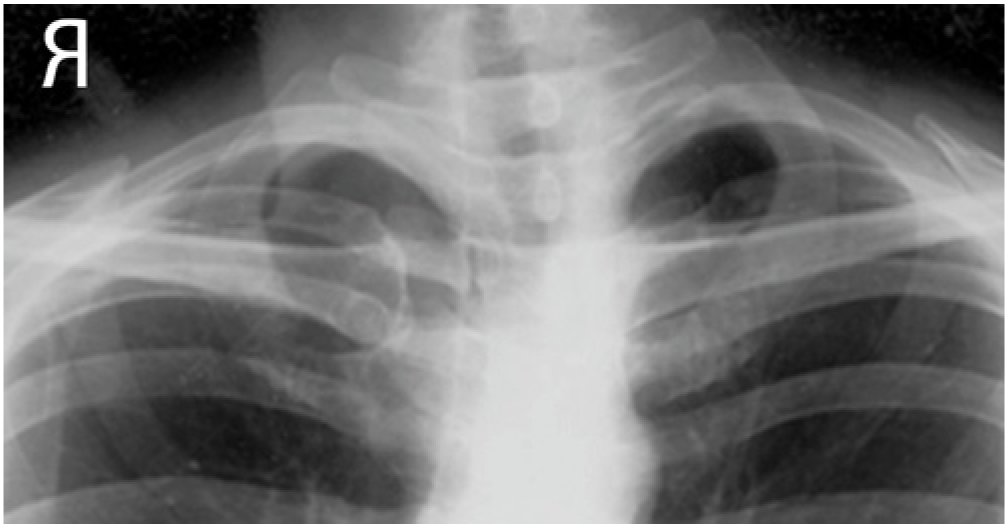


FIGURE 10.17 PA SC articulation projection taken with rotation.

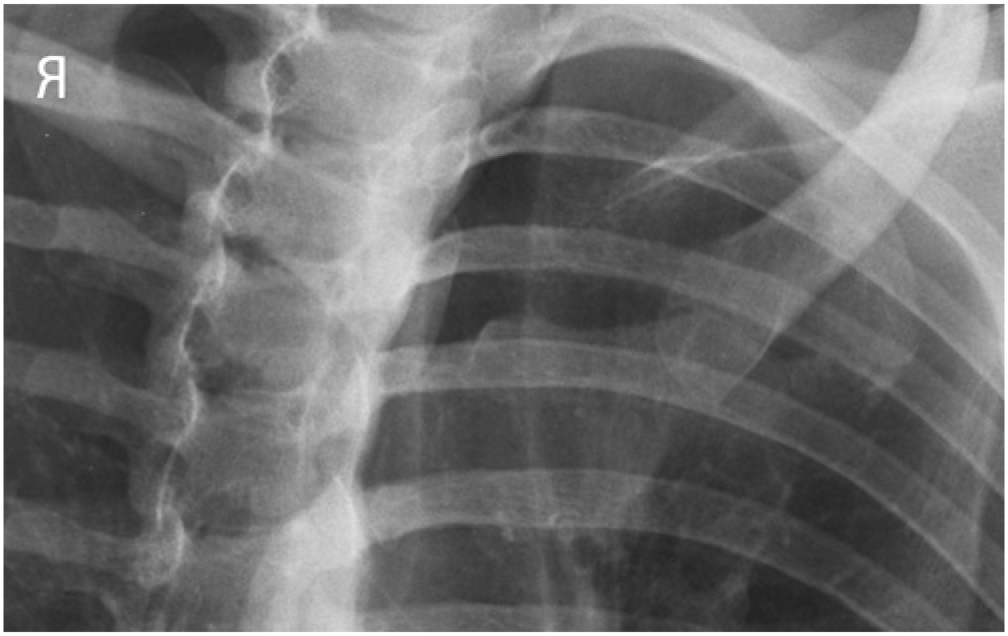


FIGURE 10.18 PA oblique sternoclavicular articulation projection with accurate positioning.

Sternoclavicular (SC) Articulations: PA Oblique Projection

See **Table 10.5** and **Figs. 10.18** and **10.19**.

Insufficient Torso Obliquity

If a portion of the sternum or medial clavicle is superimposed by the patient and the SC articulation is obscured, the torso was rotated less than 10 to15 degrees with the IR (**Fig. 10.20**).

FIGURE 10.19 Proper patient positioning for PA oblique sternoclavicular articulation projection.

TABLE 10.5

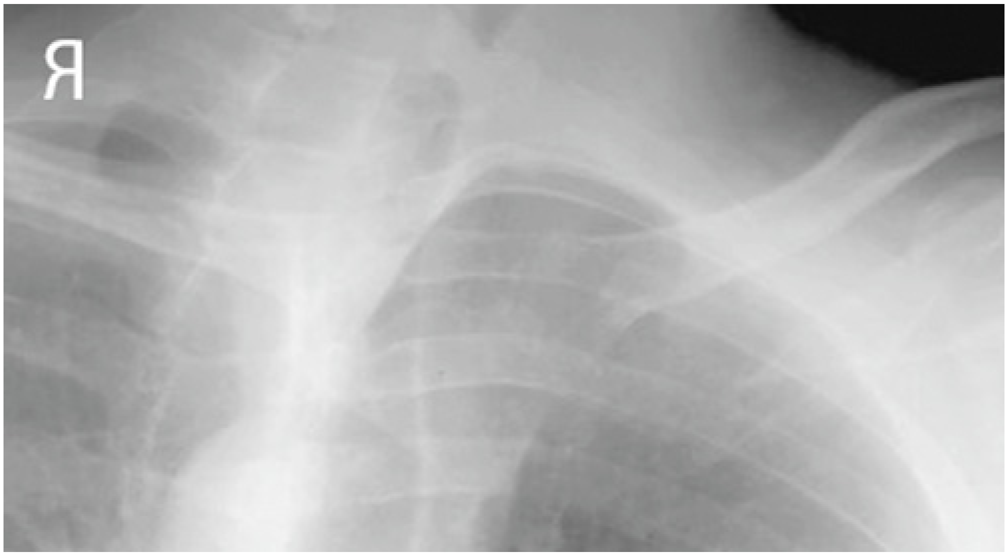


FIGURE 10.20 PA oblique SC articulation projection taken with insufficient patient obliquity.

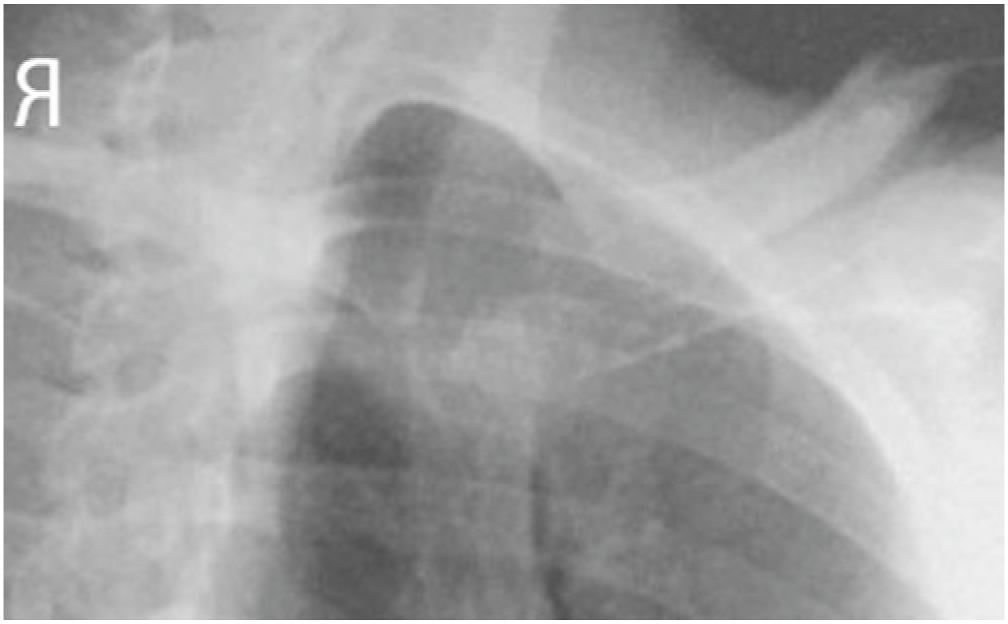


FIGURE 10.21 PA oblique SC articulation projection taken with excessive patient obliquity.

Excessive Torso Obliquity

If the SC articulation is closed and not positioned next to the spine, the torso was rotated more than 10 to 15 degrees with the IR (**Fig. 10.21**).

Ribs: AP or PA Projection (Above or Below Diaphragm)

See **Table 10.6** and Figs. **10.22–10.25**.

Soft Tissue Structures of Interest

The demonstration of the soft tissue structures that surround the ribs is very important. When an upper rib fracture is suspected, the surrounding upper thorax, axillary, neck soft tissues, and vascular lung markings are carefully studied for signs (e.g., hematoma, presence of air) that indicate associated lung pathology (e.g., pneumothorax, interstitial emphysema) or rupture of the trachea, bronchus, or aorta. When a lower rib fracture is suspected, the upper abdominal tissue is examined for signs of associated injury to the kidney, liver, spleen, or diaphragm.

Rib Marker

To help the reviewer better identify the exact area of concern on AP/PA rib projections a rib marker (BB) is taped to the patient's skin near the area where the ribs are tender. The marker shows up as a small white dot on the resulting projection (**Fig. 10.26**).

AP Versus PA Projection

When the patient complains of anterior rib pain, take a PA projection to place the anterior ribs closer to the IR. When the posterior ribs are the affected ribs, take an AP projection to place the posterior ribs closer to the IR. Compare the difference in posterior rib detail sharpness in **Figs. 10.22**

and **10.23**. **Fig. 10.22** was obtained in an AP projection and **Fig. 10.23** in a PA projection. Note how the posterior ribs in **Fig. 10.23** are magnified, demonstrating less detail sharpness than the posterior ribs in **Fig. 10.22**, which were positioned closer to the IR for the projection.

AP Projection: Rotation

When an AP projection of the ribs demonstrates rotation, the side of the chest positioned closer to the IR demonstrates the medial clavicular end situated away from the lateral edge of the vertebral column and demonstrates a greater distance from the spinous processes to that side's pedicles when compared to the opposite side (**Fig. 10.27**).

PA Projection: Rotation

When a PA projection of the ribs demonstrates rotation, the side of the chest positioned closer to the IR demonstrates the medial clavicular end that is superimposed by the vertebral column and demonstrates less distance from the spinous processes to that side's pedicles when compared to the opposite side (**Fig. 10.28**).

Scoliotic Patient

In projections of patients with spinal scoliosis, the ribs and vertebral column will appear rotated because of the lateral deviation of the vertebrae (**Fig. 10.29**). Become familiar with this condition to prevent unnecessarily repeated procedures on these patients.

Scapula Positioning

Abducting and internally rotating the affected arm moves the scapula laterally, positioning it outside the lung field. Failing to abduct and

internally rotate the affected arm demonstrates the scapula in the lung field and may obscure the ribs of interest (**Fig. 10.30**).

Above-Diaphragm Ribs: Respiration

The number of ribs located above or below the diaphragm is determined by the depth of patient inspiration. In full suspended inspiration, up to 10 axillary ribs may be demonstrated above the diaphragm. In expiration, only seven or eight axillary ribs are clearly visible above the diaphragm, and four or five ribs are demonstrated below the diaphragm. When the above-diaphragm ribs are imaged, take the exposure on full inspiration to maximize the number of ribs located above the diaphragm. Any ribs situated below the diaphragm will not be well demonstrated because the increase in exposure would be needed to demonstrate the abdominal tissue they surround (**Fig. 10.31**).

TABLE 10.6

AP, Anteroposterior; *CR,* central ray; *IR,* image receptor; *PA,* posteroanterior.

Below-Diaphragm Ribs: Respiration

When below-diaphragm ribs are imaged, it is necessary to use a higher kV and exposure than needed for the above-diaphragm ribs to penetrate the denser abdominal tissue. Any ribs situated above the diaphragm for this projection may have insufficient brightness to evaluate (**Fig. 10.32**). To

maximize the number of ribs located below the diaphragm, take the exposure on full suspended expiration.

Bilateral AP/PA Projection

If the patient has both right- and left-side rib pain, the exam may be obtained bilaterally (**Fig. 10.33**). This is accomplished by centering the central ray (CR) to the midsagittal plane at the appropriate level for above- or below-diaphragm projections. The transverse collimation should be opened to 0.5 inch (1.25 cm) from the lateral ribs.

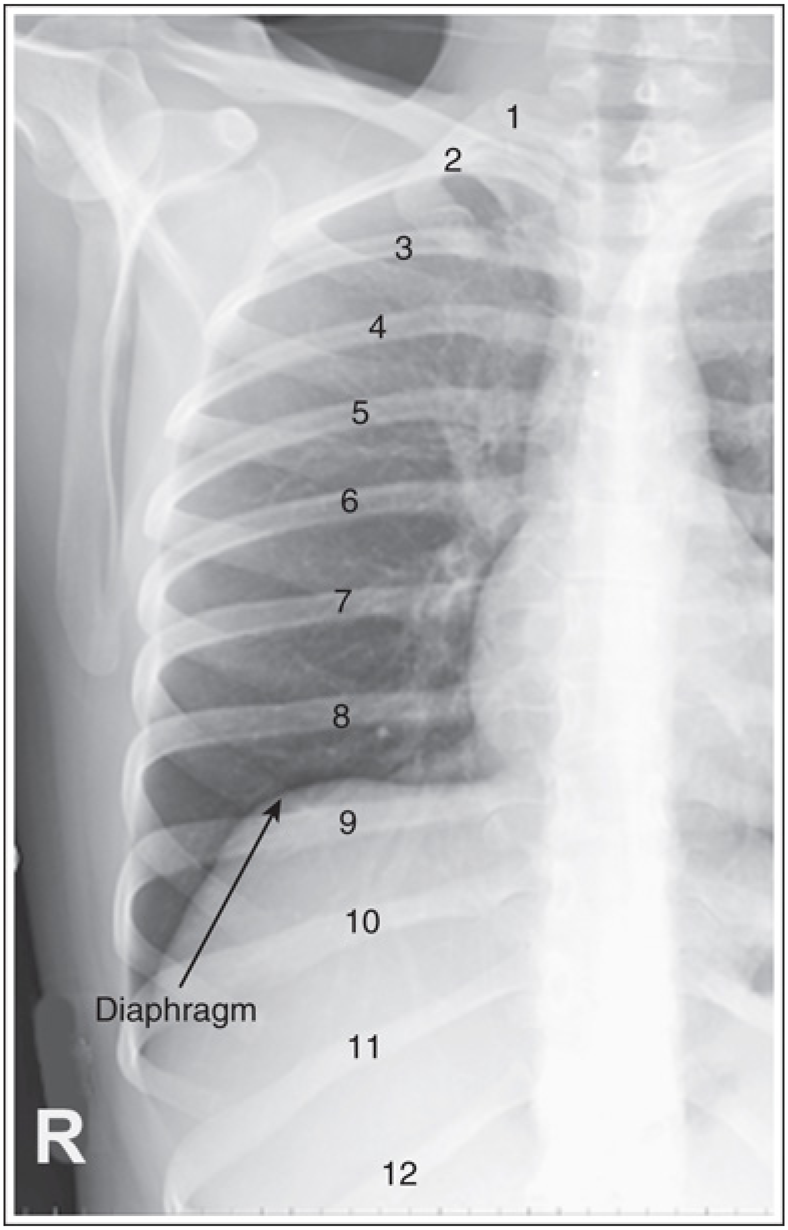


FIGURE 10.22 AP above-diaphragm rib projection with accurate positioning.

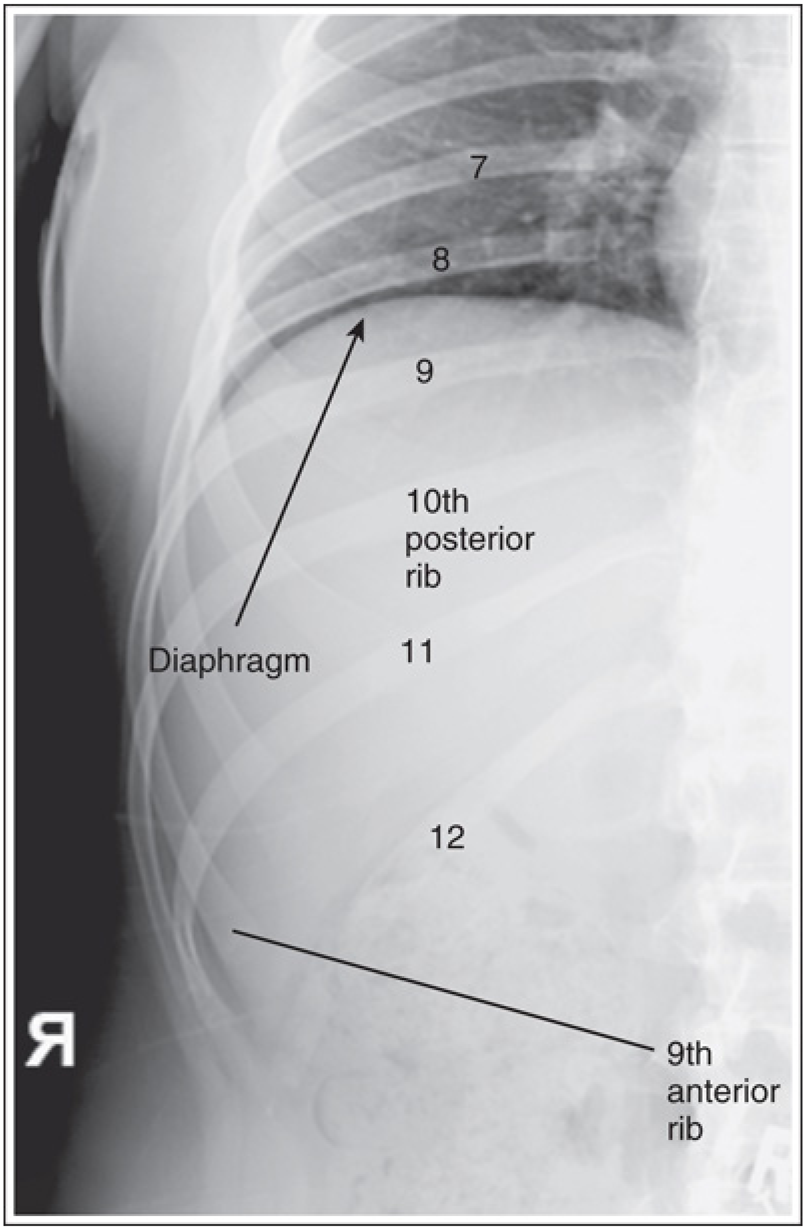


FIGURE 10.23 PA below-diaphragm rib projection with accurate positioning.

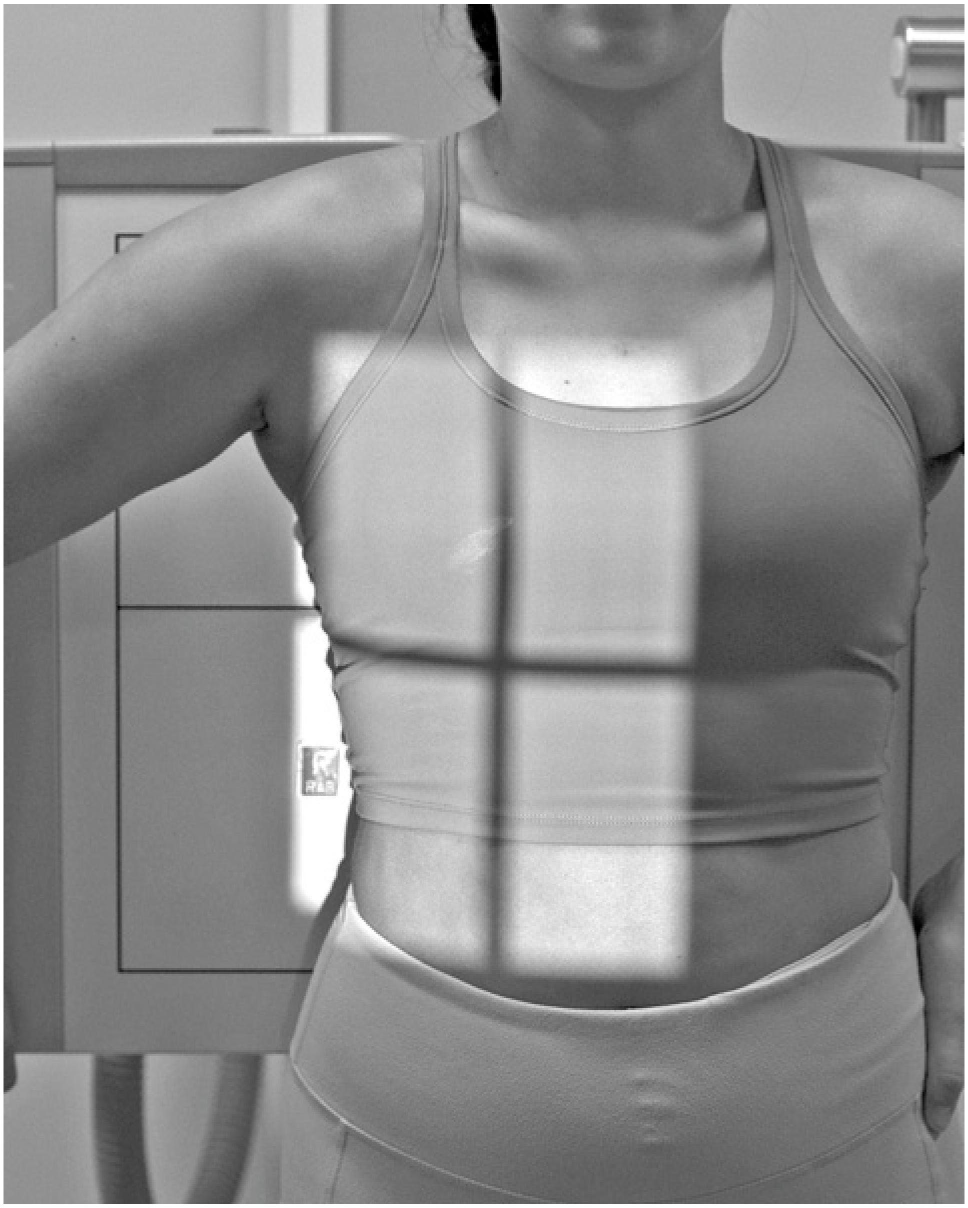


FIGURE 10.24 Proper patient positioning for AP below-diaphragm rib projection.

FIGURE 10.25 Proper patient positioning for PA above-diaphragm rib projection.

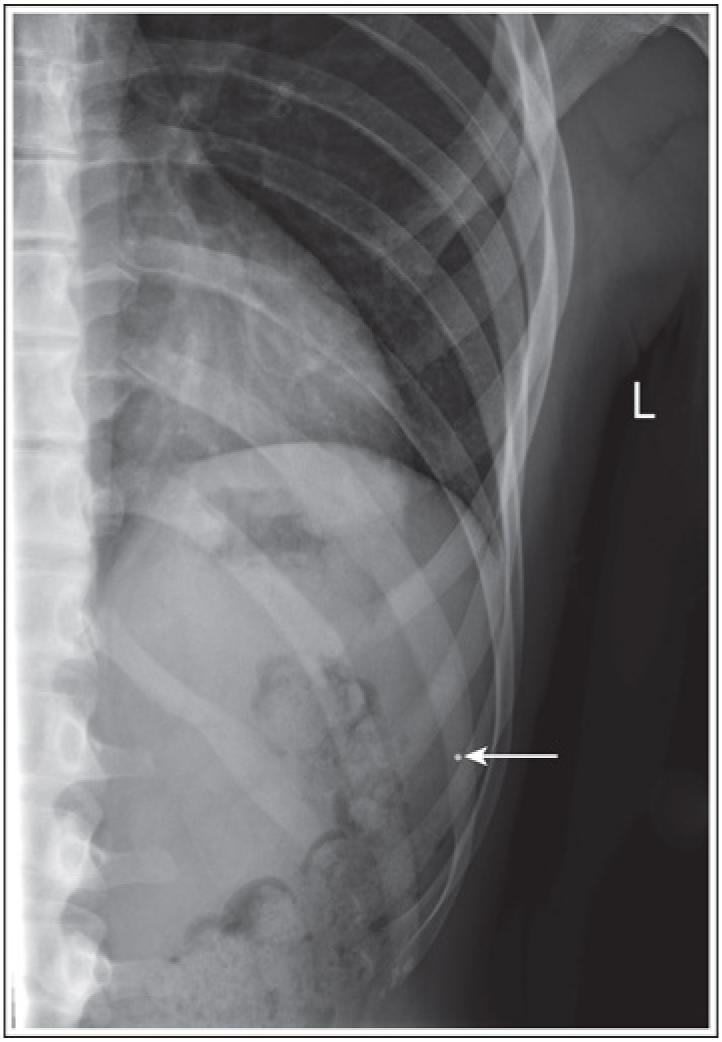


FIGURE 10.26 AP below-diaphragm rib projection demonstrating a rib marker *(arrow)*.

FIGURE 10.27 AP above-diaphragm rib projection taken with the patient rotated toward the right side.

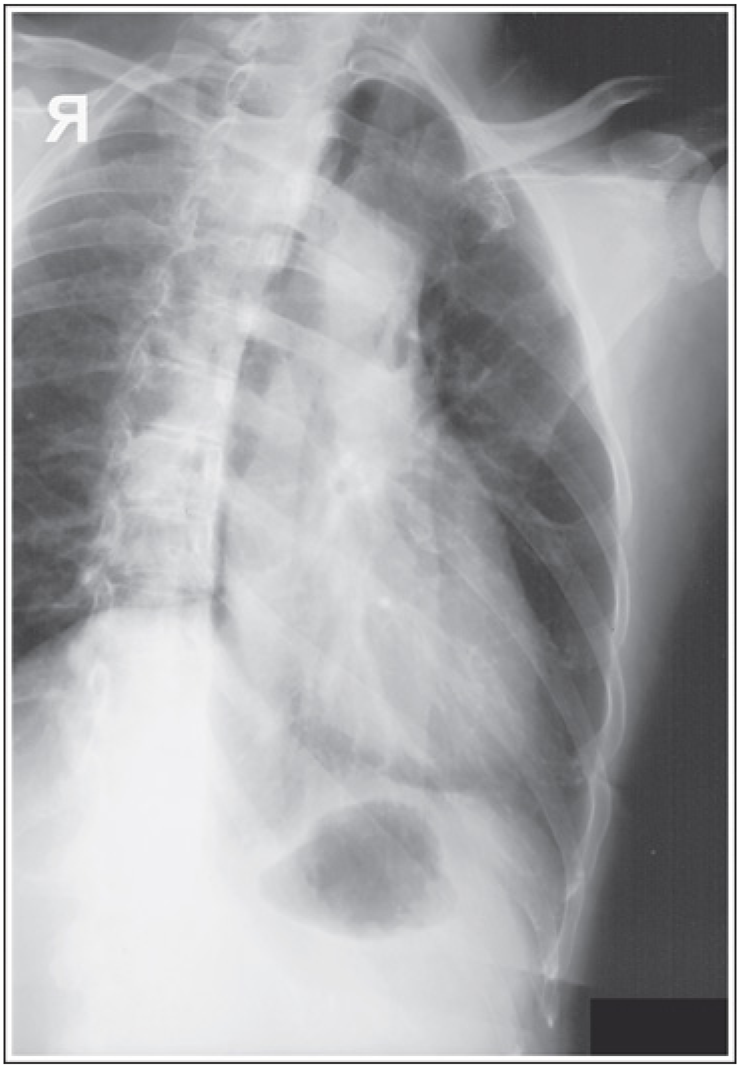


FIGURE 10.28 PA above-diaphragm rib projection taken with the patient rotated toward the right side.

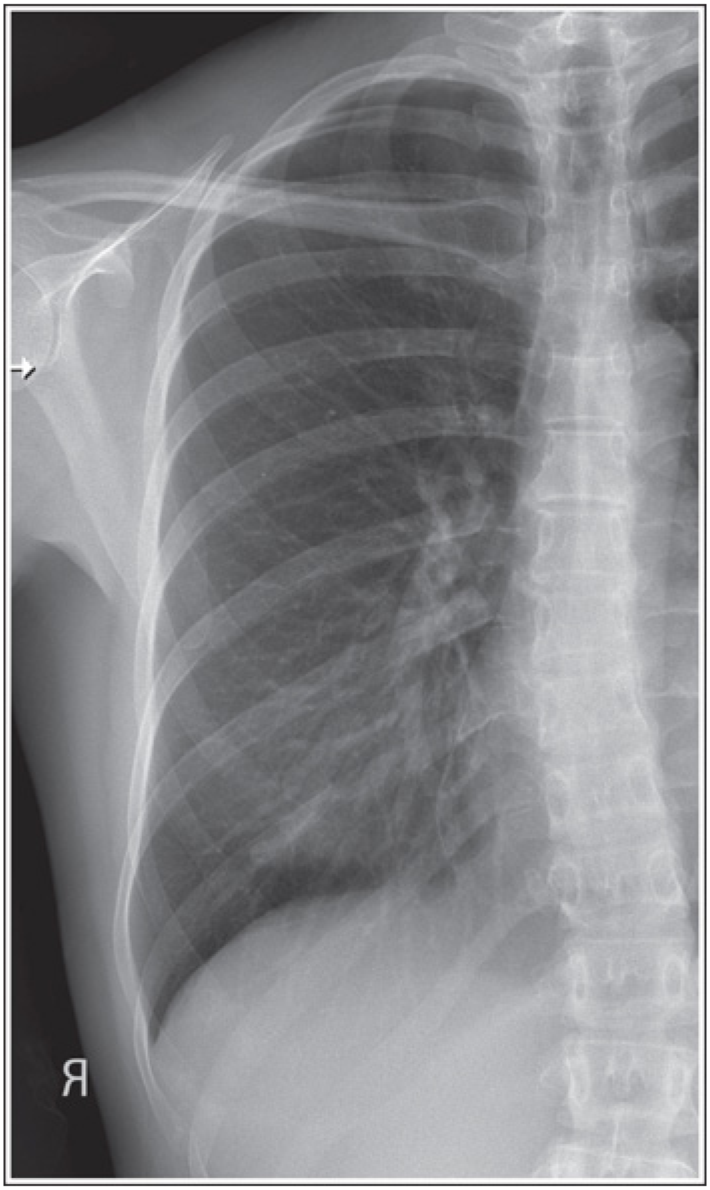


FIGURE 10.29 PA above-diaphragm rib projection taken of a patient with slight spinal scoliosis.

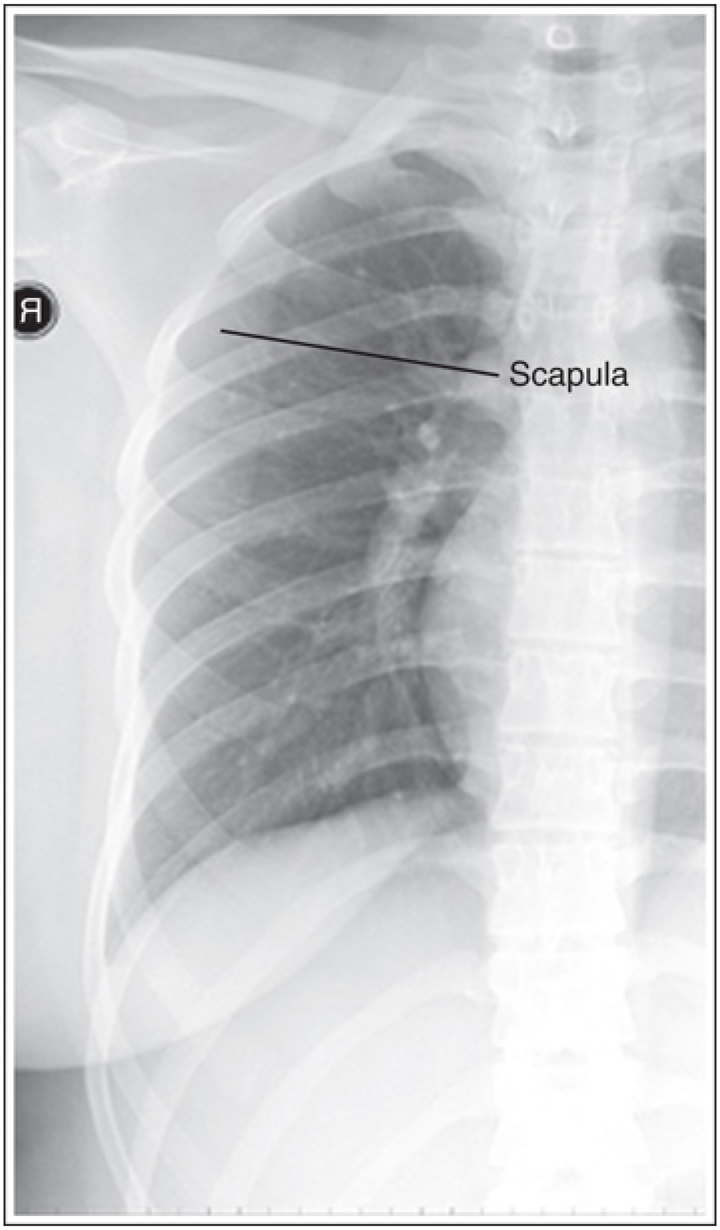


FIGURE 10.30 PA above-diaphragm rib projection taken without the right elbow and shoulder rotated anteriorly.

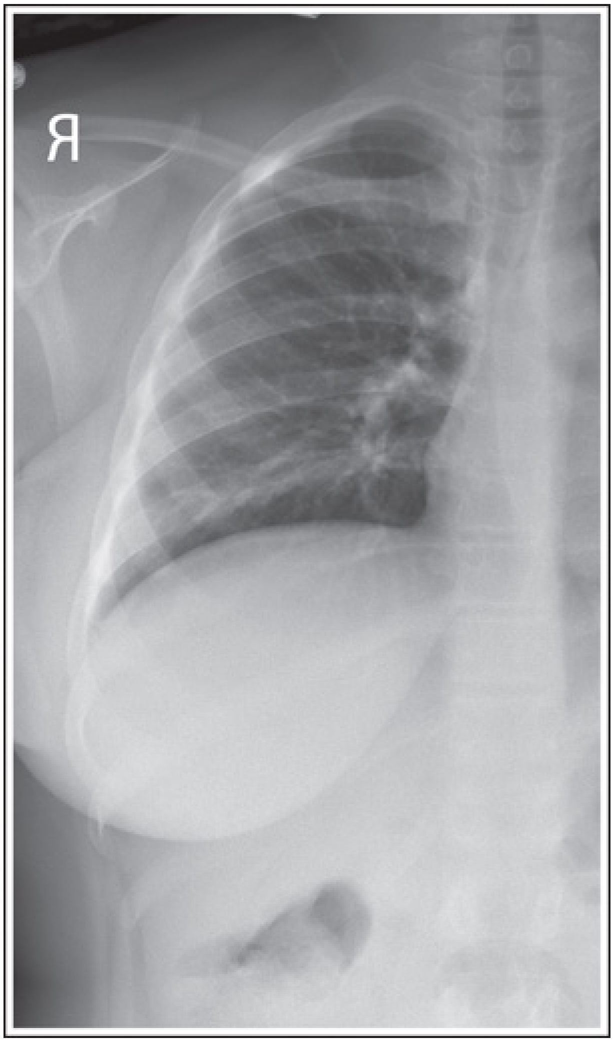


FIGURE 10.31 PA above-diaphragm rib projection taken after expiration.

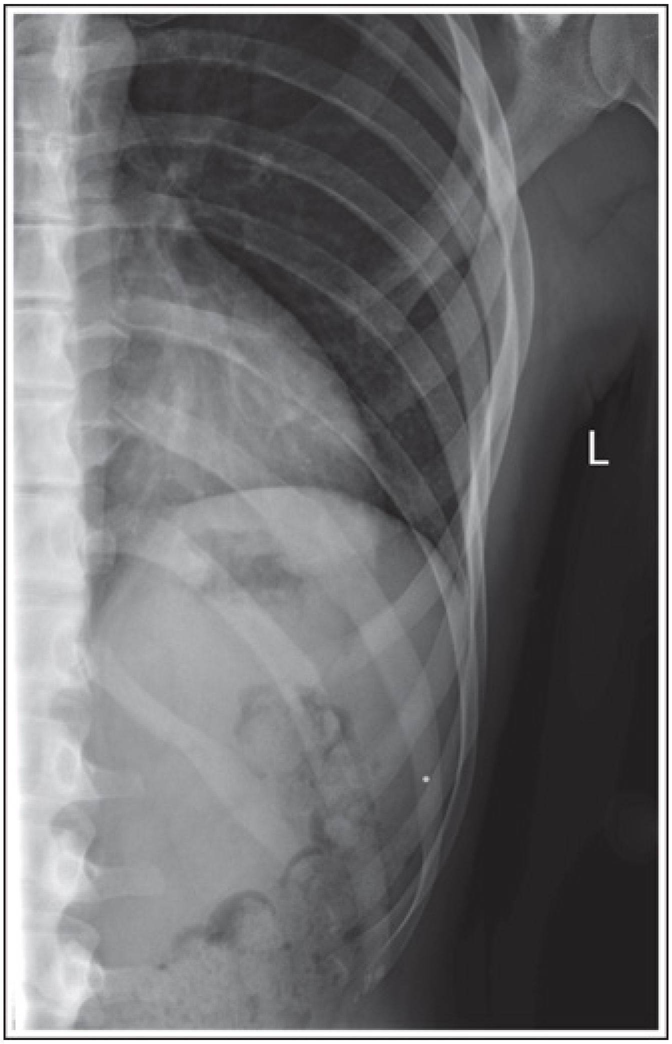


FIGURE 10.32 PA below-diaphragm rib projection taken after inspiration.

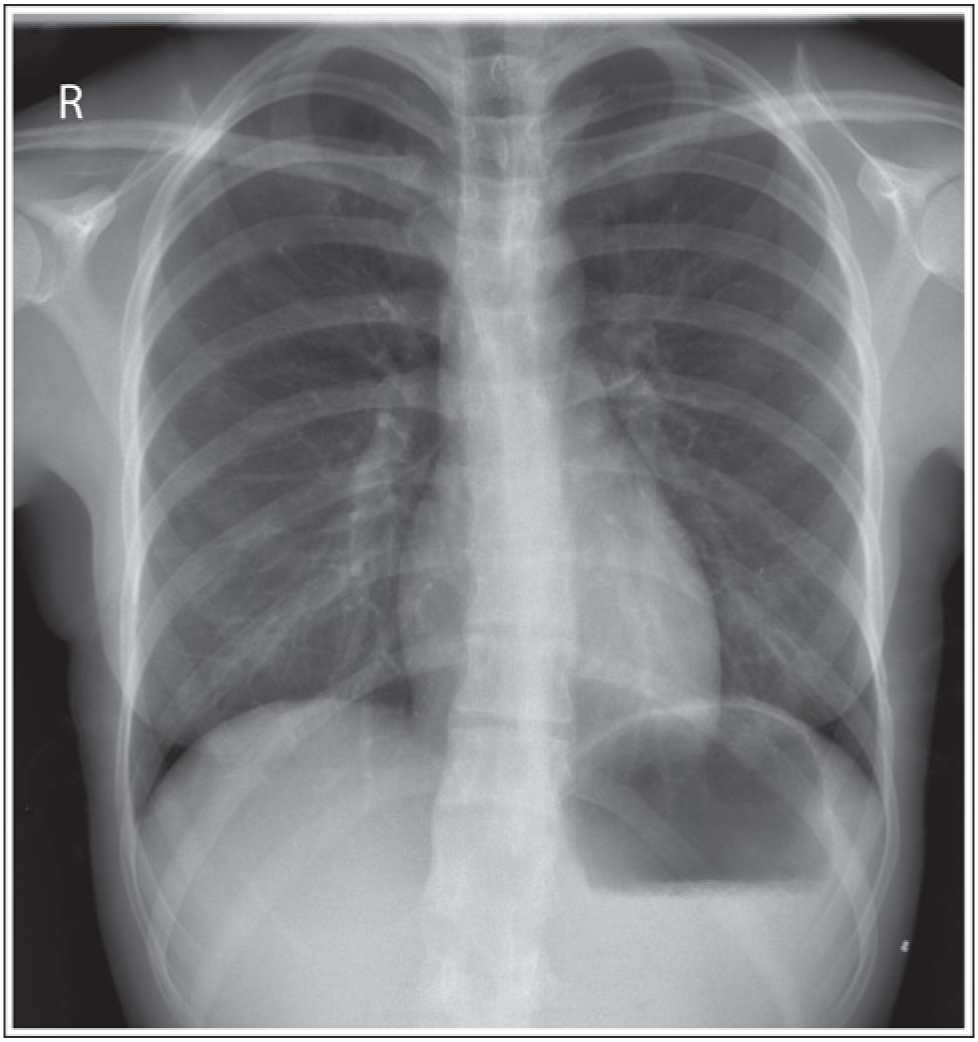


FIGURE 10.33 Bilateral above-diaphragm AP rib projection with accurate positioning.

AP/PA Rib Projection Analysis Practice

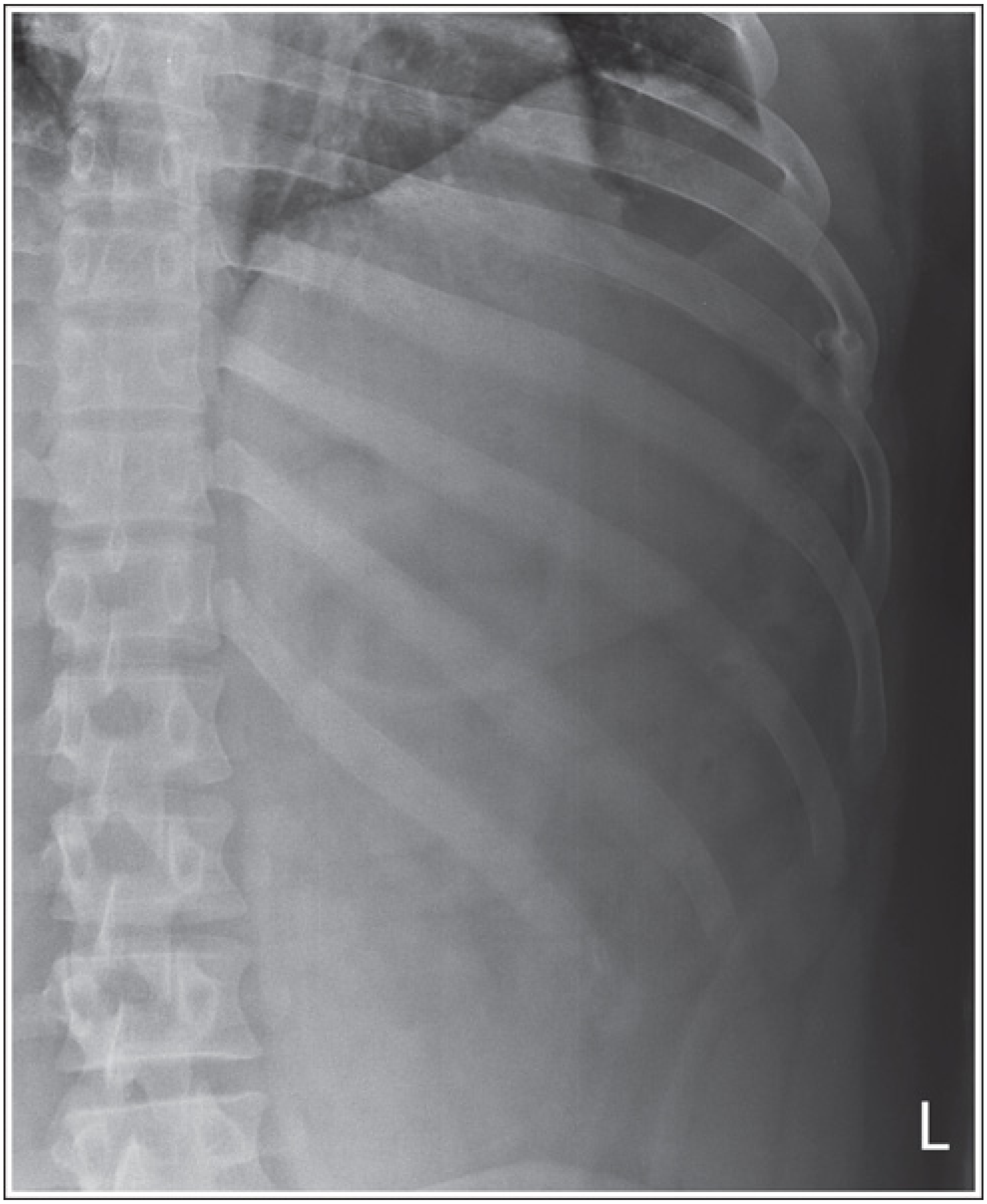


IMAGE 10.2

AP BELOW-DIAPHRAGM.

Analysis

The distance from the spinous processes to the left lumbar pedicles is larger than the same distance from the right pedicles to the spinous processes. The chest was rotated toward the left side.

Correction

Rotate the chest toward the right side until the midcoronal plane is parallel with the IR.

Ribs: AP Oblique Projection (RPO and LPO Positions)

See **Table 10.7** and Figs. **10.34**–**10.37**.

Controlling Magnification

Oblique ribs may be performed using AP and PA oblique projections, but to provide maximum axillary rib detail, the AP oblique projection (right posterior oblique [RPO] and left posterior oblique [LPO] positions) should be routinely performed. In the AP oblique projection (see **Fig. 10.34**), the axillary ribs are placed closer to the IR than in the PA oblique projection (**Fig. 10.38**), resulting in less rib magnification and greater recorded detail.

Chest Incorrectly Rotated

If the chest is rotated away from the affected side for an AP oblique ribs projection instead of toward the affected side, the axillary ribs will demonstrate increased foreshortening (**Fig. 10.39**).

Insufficient Chest and Rib Obliquity

Because the sternum rotates toward the affected axillary ribs when the chest is accurately rotated for an AP oblique ribs projection, the position of the sternum can be used to identify the accuracy of chest rotation and openness

of the axillary ribs. If the sternum is positioned halfway between the vertebral column and the anterior ribs, the chest was rotated 45 degrees and the axillary ribs are “opened.” If the sternum is demonstrated next to the vertebral column, the chest was insufficiently rotated and the axillary ribs are foreshortened (**Fig. 10.40**).

TABLE 10.7

AP, Anteroposterior; *CR,* central ray; *IR,* image receptor.

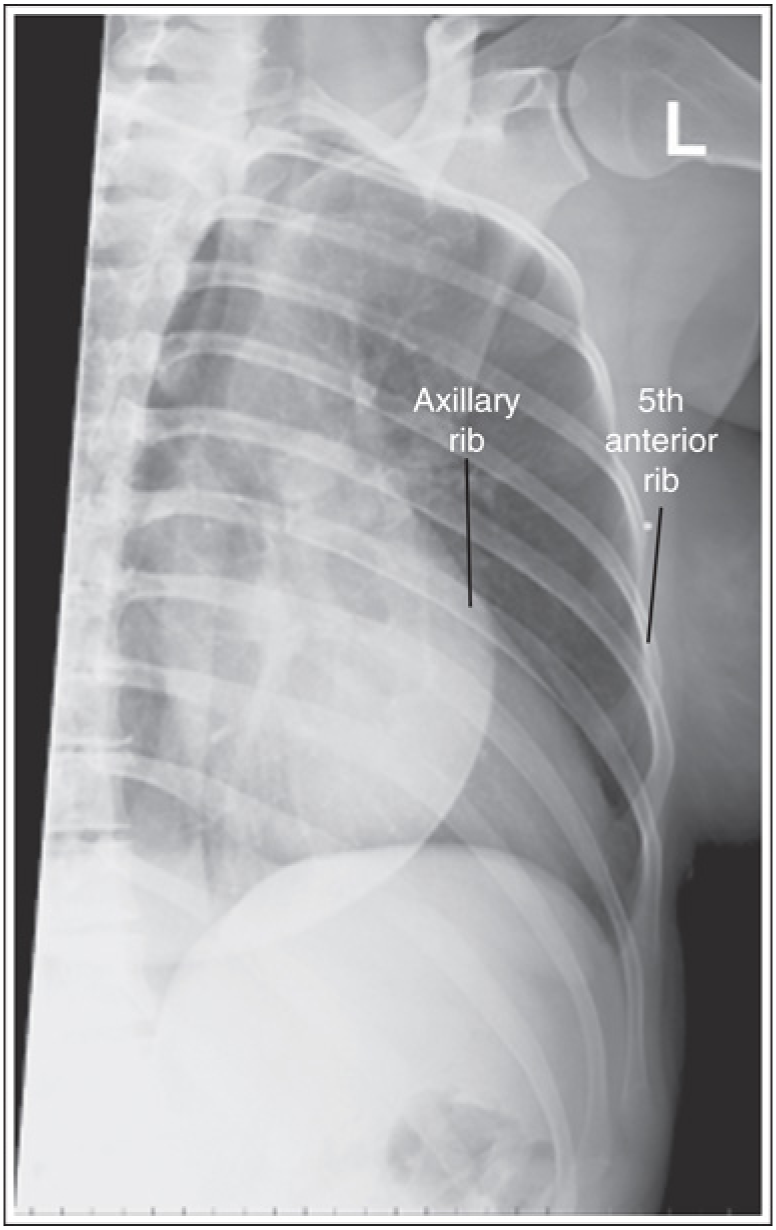


FIGURE 10.34 AP oblique above-diaphragm rib projection (LPO position) with accurate positioning.

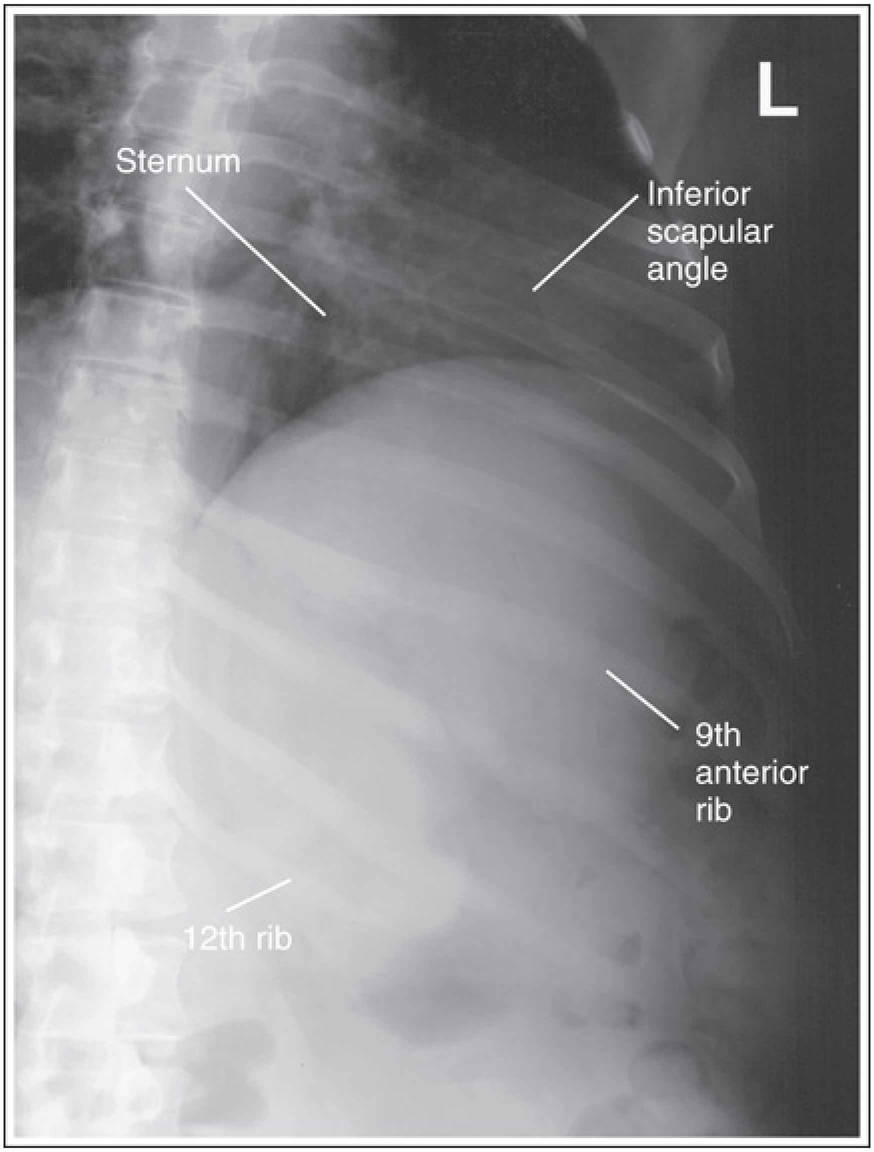


FIGURE 10.35 AP oblique below-diaphragm rib projection (LPO position) with accurate positioning.

FIGURE 10.36 Proper patient positioning for AP oblique above-diaphragm rib projection (RPO position).

FIGURE 10.37 Proper patient positioning for AP oblique below-diaphragm rib projection (RPO position).

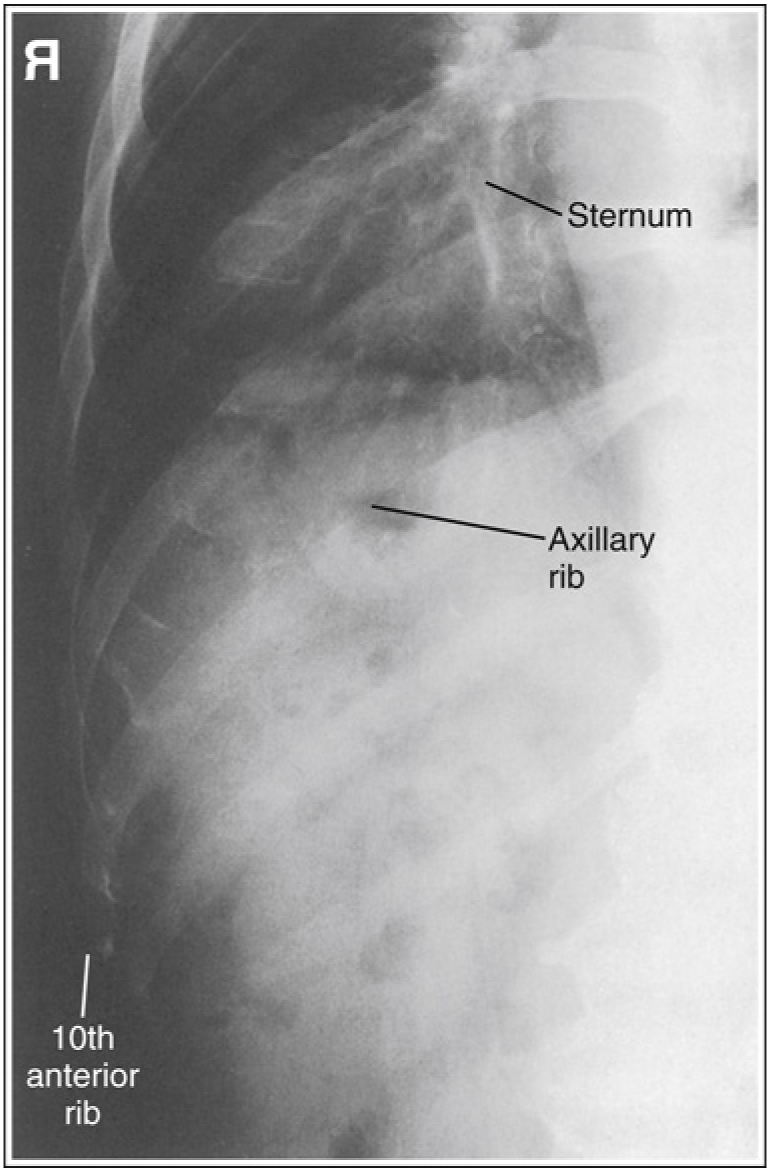


FIGURE 10.38 PA oblique below-diaphragm rib projection demonstrating magnified axillary ribs.

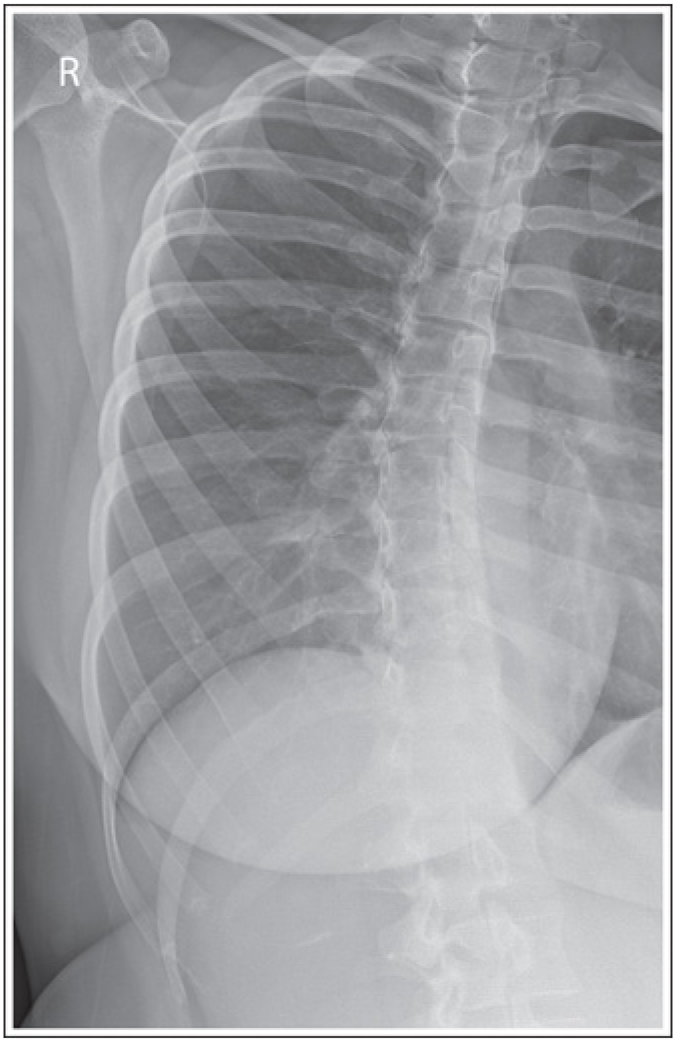


FIGURE 10.39 AP oblique below-diaphragm rib projection with patient rotated in the wrong direction.

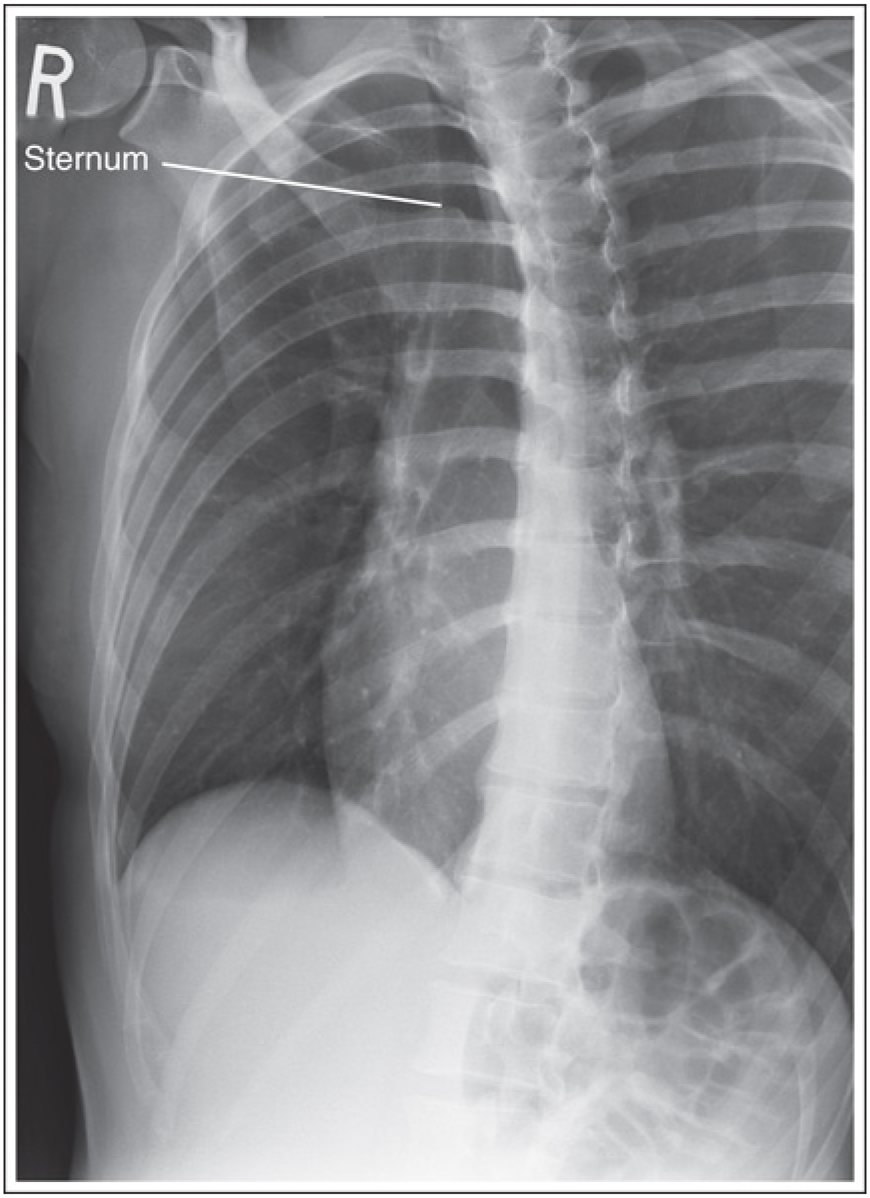


FIGURE 10.40 AP oblique above-diaphragm rib projection demonstrating insufficient patient obliquity.

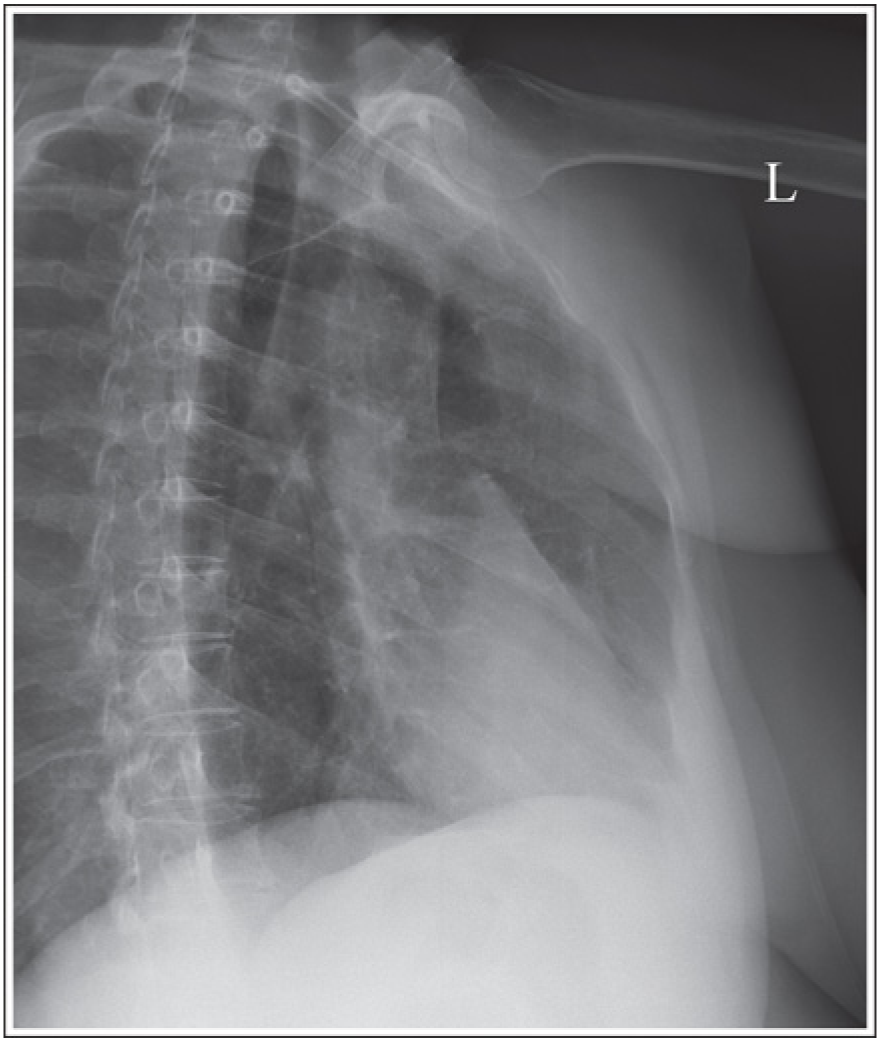


FIGURE 10.41 AP oblique above-diaphragm rib projection demonstrating excessive patient obliquity.

Excessive Chest Obliquity

If the sternum is demonstrated lateral to the midpoint between the vertebral column and anterior ribs, the chest was rotated more than 45 degrees (**Fig. 10.41**).

AP/PA Oblique Rib Projection Analysis Practice

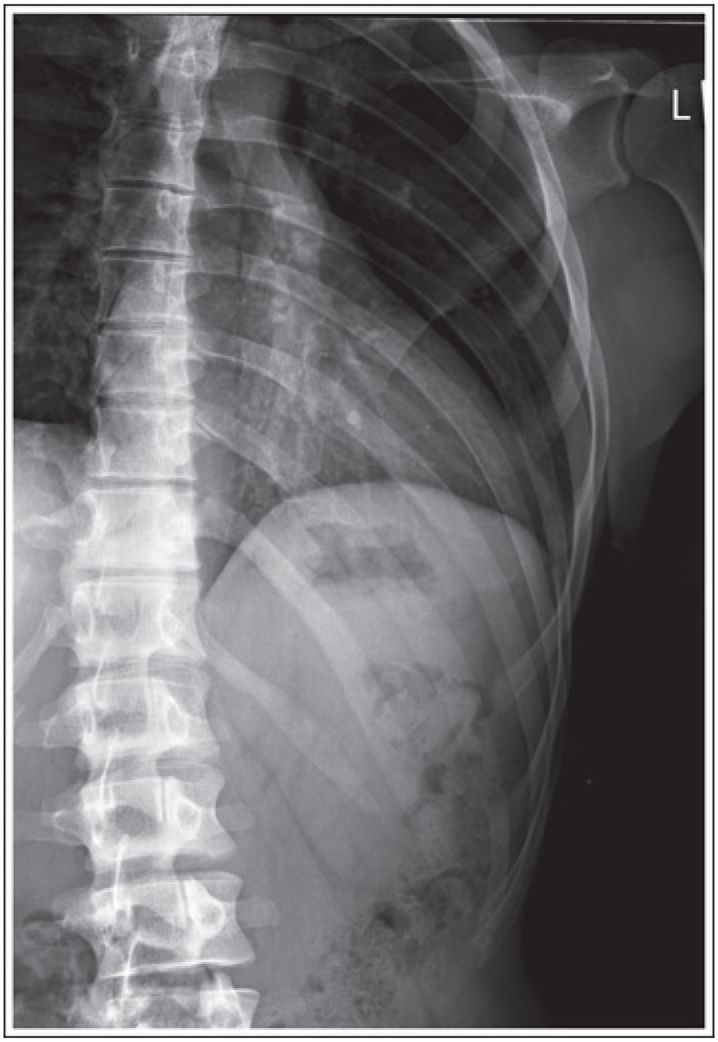


IMAGE 10.3

AP OBLIQUE BELOW-DIAPHRAGM.

Analysis

The inferior sternal body is demonstrated next to the vertebral column; the chest was insufficiently rotated. The eighth and most of the ninth posterior rib are seen above the diaphragm. The exam was not obtained after full expiration.

Correction

Increase the degree of rotation until the midcoronal plane is at a 45-degree angle with the IR and take the exposure after expiration.

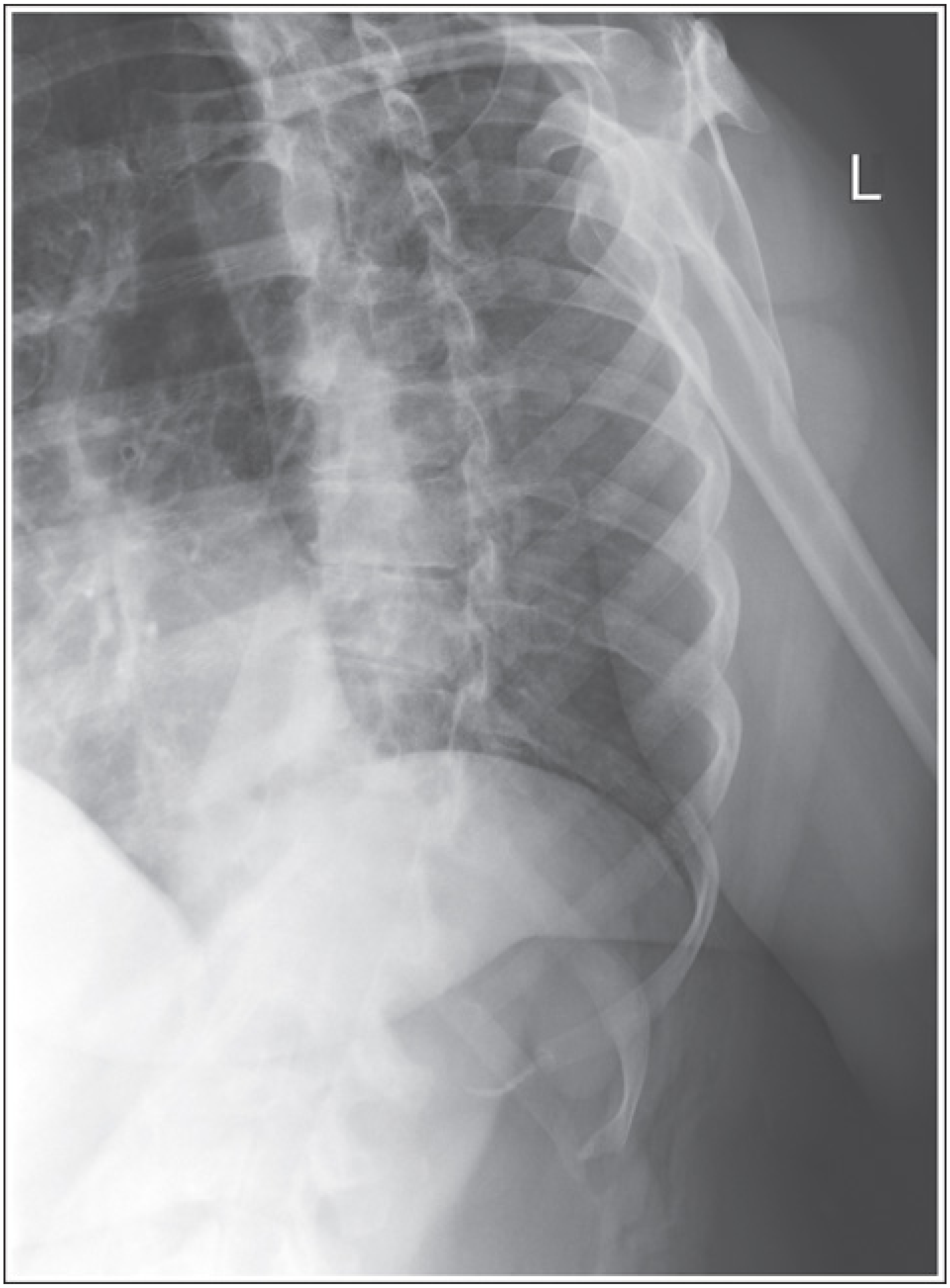


IMAGE 10.4

AP OBLIQUE BELOW-DIAPHRAGM.

Analysis

The left-side axillary ribs demonstrate excessive foreshortening. The chest was rotated the wrong direction.

Correction

Rotate the patient into an LPO 45-degree position.

Chapter 11: Image Analysis of the Cranium

OBJECTIVES

After completion of this chapter, you should be able to do the following:

- Identify the required anatomy on cranial, facial bone, nasal bones, mandible, and sinus projections.
- Describe how to position the patient, image receptor (IR), and central ray (CR) properly on cranial, facial bone, nasal bones, mandible, and sinus projections.

- List the analysis guidelines for cranial, facial bone, nasal bones, mandible, and sinus projections with accurate positioning.
- State how to reposition the patient properly when cranial, facial bone, nasal bones, mandible, and sinus projections with poor positioning are produced.
- Discuss how to determine the amount of patient or CR adjustment required to improve cranial, facial bone, nasal bones, mandible, and sinus projections with poor positioning.
- State the kilovoltage routinely used for cranial, facial bone, nasal bones, mandible, and sinus projections, and describe which anatomic structures are visible when the correct technique factors are used.
- State how the CR is adjusted to obtain accurate cranial positioning when the patient has a suspected cervical injury or is unable to adequately align the head with the IR.
- Define and state the common abbreviations used for the cranial positioning lines.
- Discuss why the parietoacanthial projection (Waters method) is taken with the mouth open.
- Explain how the patient and CR are positioned to demonstrate accurate air-fluid levels in the sinus cavities.

KEY TERMS

lips-meatal line (LML)

mentomeatal line (MML)

orbitomeatal line (OML)

Image Analysis Guidelines

Technical Data

See **Table 11.1** and **Box 11.1**.

Cranial Positioning Landmarks

Table 11.2 lists and defines the cranial positioning landmarks used in the information presented.

Cranium and Mandible: PA or AP Projection

See **Table 11.3** and Figs. **11.1–11.3**.

Cranium: Rotation

Positioning the midsagittal plane perpendicular to the image receptor (IR) prevents cranial rotation. A method of accomplishing this goal is to place an extended flat palm next to each lateral parietal bone. Then adjust the head rotation until your hands are perpendicular to the IR and parallel with each other. Head rotation is present on a posteroanterior (PA)/anteroposterior (AP) projection if the distance from the lateral margins of orbit to the lateral cranial cortices on one side is greater than on the other side (**Fig. 11.4**). The face was rotated away from the side demonstrating the greater distance.

TABLE 11.1

AEC, Automatic exposure control; *AP*, anteroposterior; *PA*, posteroanterior; *SID*, source–image receptor distance.

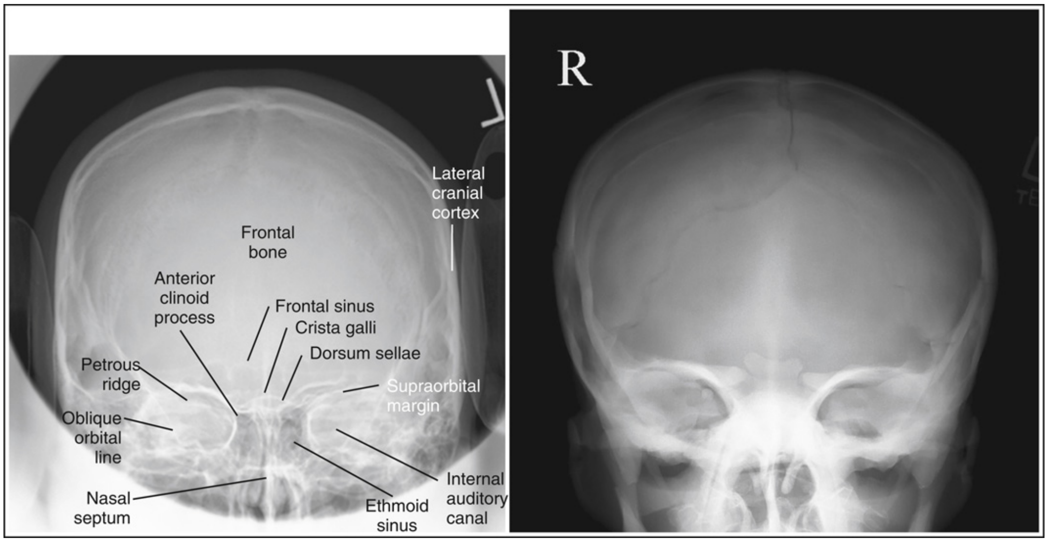


FIGURE 11.1 PA and AP cranial projections with accurate positioning.

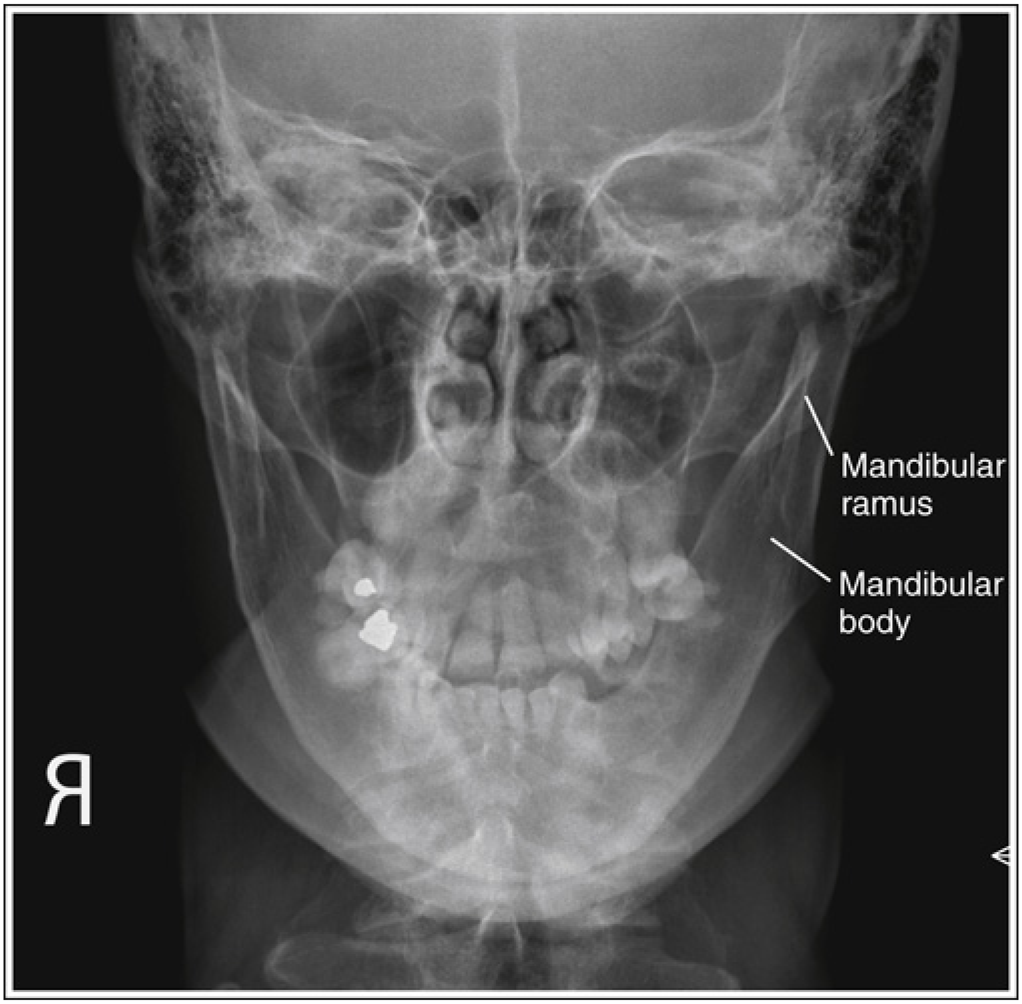


FIGURE 11.2 PA mandible projection with accurate positioning.

TABLE 11.2

TABLE 11.3

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor; *OML*, orbitomeatal line; *PA*, posteroanterior; *TMJ*, temporomandibular joint.

Box 11.1 Cranium, Facial Bones, Nasal Bones, and Paranasal Sinuses Guidelines

VOI, Values of interest.

- The facility's identification requirements are visible.
- A right or left marker identifying the correct side of the patient is present on the projection and is not superimposed over the VOI.
- Good radiation protection practices are evident.
- Bony trabecular patterns and cortical outlines of the anatomic structures are sharply defined.
- Contrast resolution is adequate to demonstrate the air-filled cavities, sinuses, and mastoids and bony structures of the cranium, facial bones, nasal bones, and mandible, when present.
- No quantum mottle or saturation is present.
- Scattered radiation has been kept to a minimum.
- There is no evidence of removable artifacts.

FIGURE 11.3 Proper patient positioning for PA cranial projection.

Mandible: Rotation

Mandibular rotation is present on a PA mandible projection when the distance from the mandibular rami to the lateral cervical vertebrae is greater on one side than the other. The face was rotated away from the side

demonstrating the greater distance. The mandibular ramus demonstrating the least width will also be the side the face was turned toward (**Fig. 11.5**).

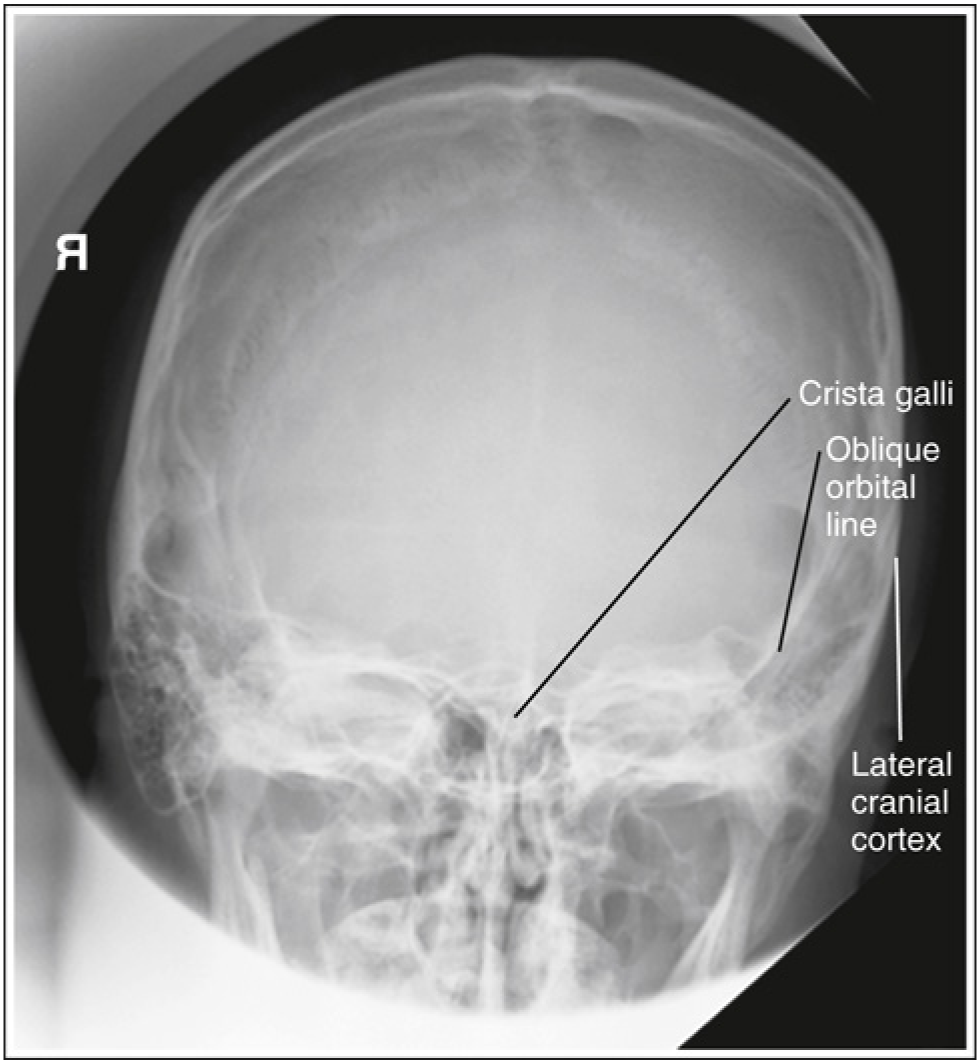


FIGURE 11.4 PA cranium projection taken with the face rotated toward the left side.

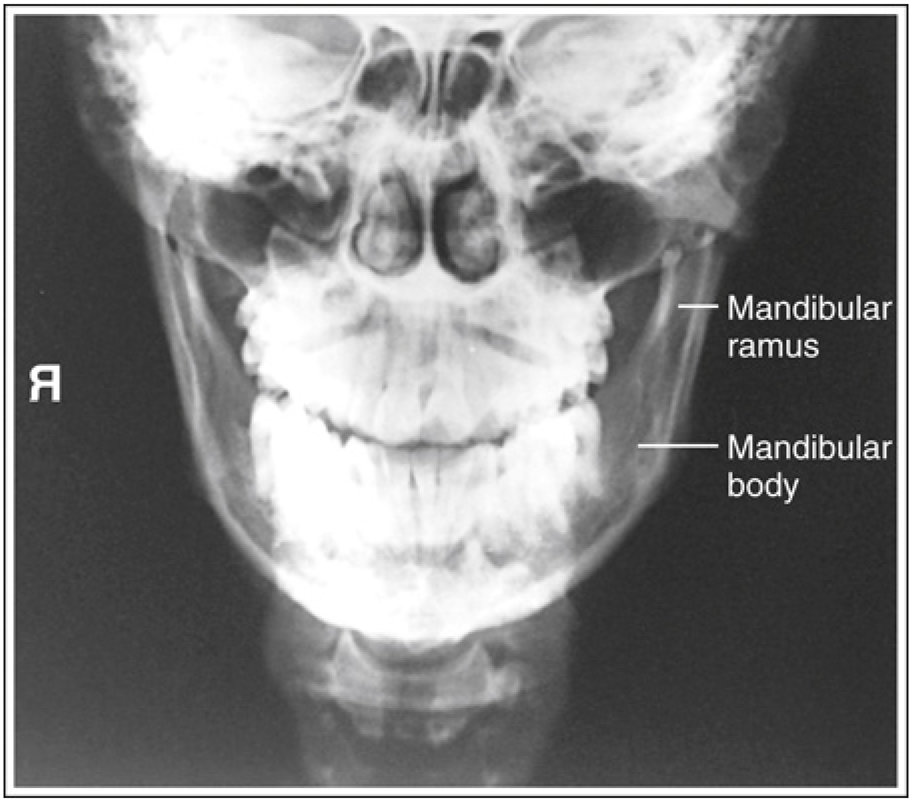


FIGURE 11.5 PA mandible projection taken with the face rotated toward the right side.

Cranium OML Alignment: Insufficient Chin Tucking

Positioning the OML perpendicular to the IR moves the orbits inferiorly until the supraorbital margins are situated beneath the petrous ridges and places the petrous pyramids and internal acoustic meatus within the orbits. Poor OML alignment is detected by evaluating the relationship of the petrous ridges and supraorbital margin. If the chin was insufficiently tucked to bring the OML perpendicular to the IR, the petrous ridges are demonstrated inferior to the supraorbital margins, the internal acoustic meatus is obscured by the infraorbital margins, and the dorsum sellae and anterior clinoids are demonstrated within the ethmoid sinuses (**Fig. 11.6**).

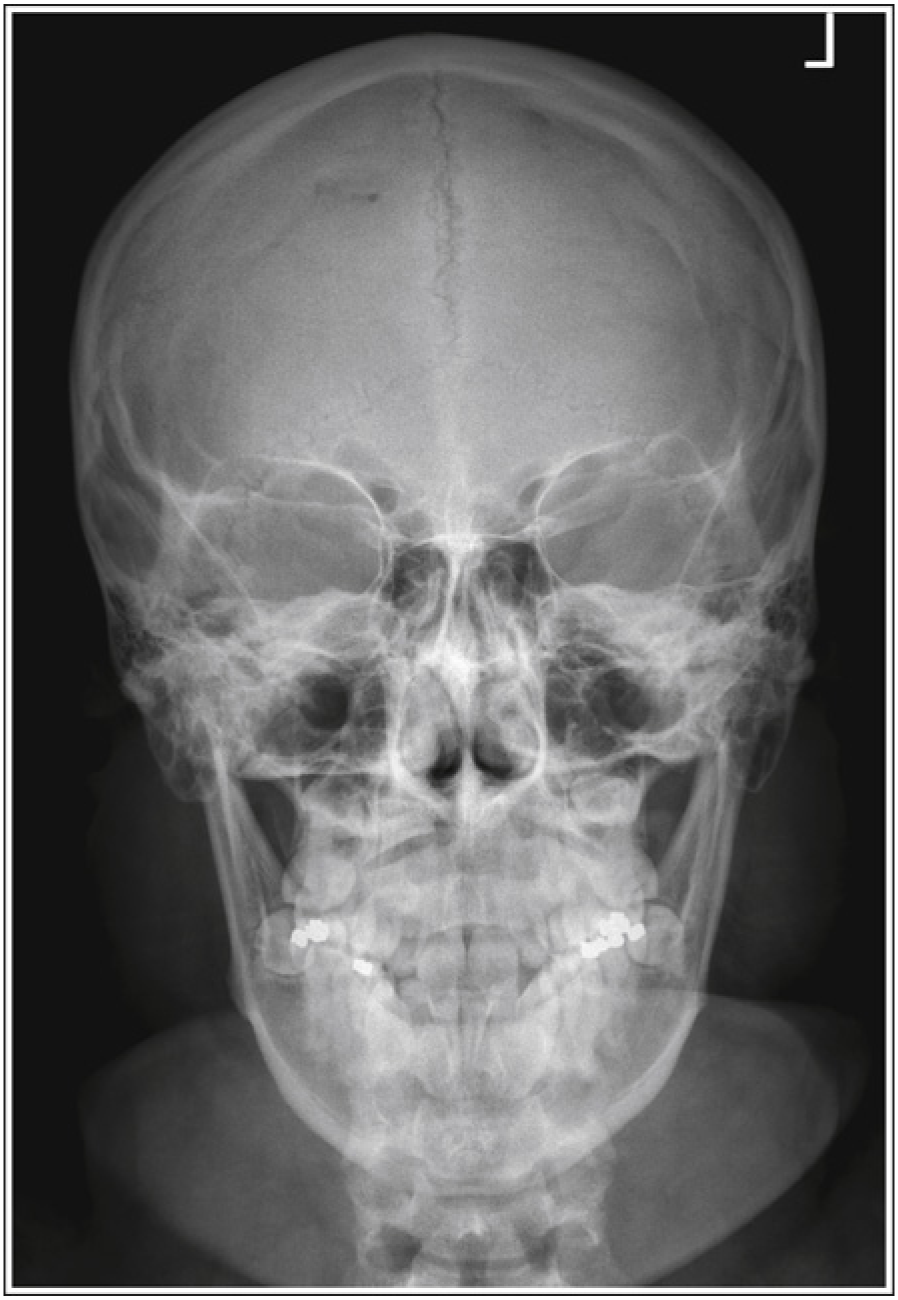


FIGURE 11.6 PA cranial projection taken with the chin insufficiently tucked to bring the OML perpendicular with the IR.

If the patient is unable to tuck the chin adequately to position the OML perpendicular to the IR, the central ray (CR) angle may be adjusted to compensate. Instruct the patient to tuck the chin to place the OML as close

as possible to perpendicular to the IR. Then angle the CR parallel with the OML; this is accomplished by aligning the collimator's transverse light line with the OML.

Cranium OML Alignment: Excessive Chin Tucking

If the chin was tucked more than needed to bring the OML perpendicular to the IR, the petrous ridges are demonstrated superior to the supraorbital margins, the internal acoustic meatus is obscured, and the dorsum sellae and anterior clinoids are visualized superior to the ethmoid sinuses (**Fig. 11.7**). When adjusting for poor OML alignment, because the petrous ridges, dorsum sellae, and anterior clinoids are centrally located in the cranium at the cranial and cervical vertebrae pivot point, the head must be adjusted the full distance demonstrated between the petrous ridges and supraorbital margins to move the patient the needed amount. For example, if the petrous ridges are demonstrated one-half inch inferior to the supraorbital margin on a less than optimal projection, the chin would need to be tucked one-half inch to superimpose the petrous ridges and supraorbital margin and obtain an optimal projection. (See the “Steps for Repositioning the Patient for Repeat Projections” section in **Chapter 1** [**Tables 1.6 and 1.7**] for a more complete discussion on this subject.)

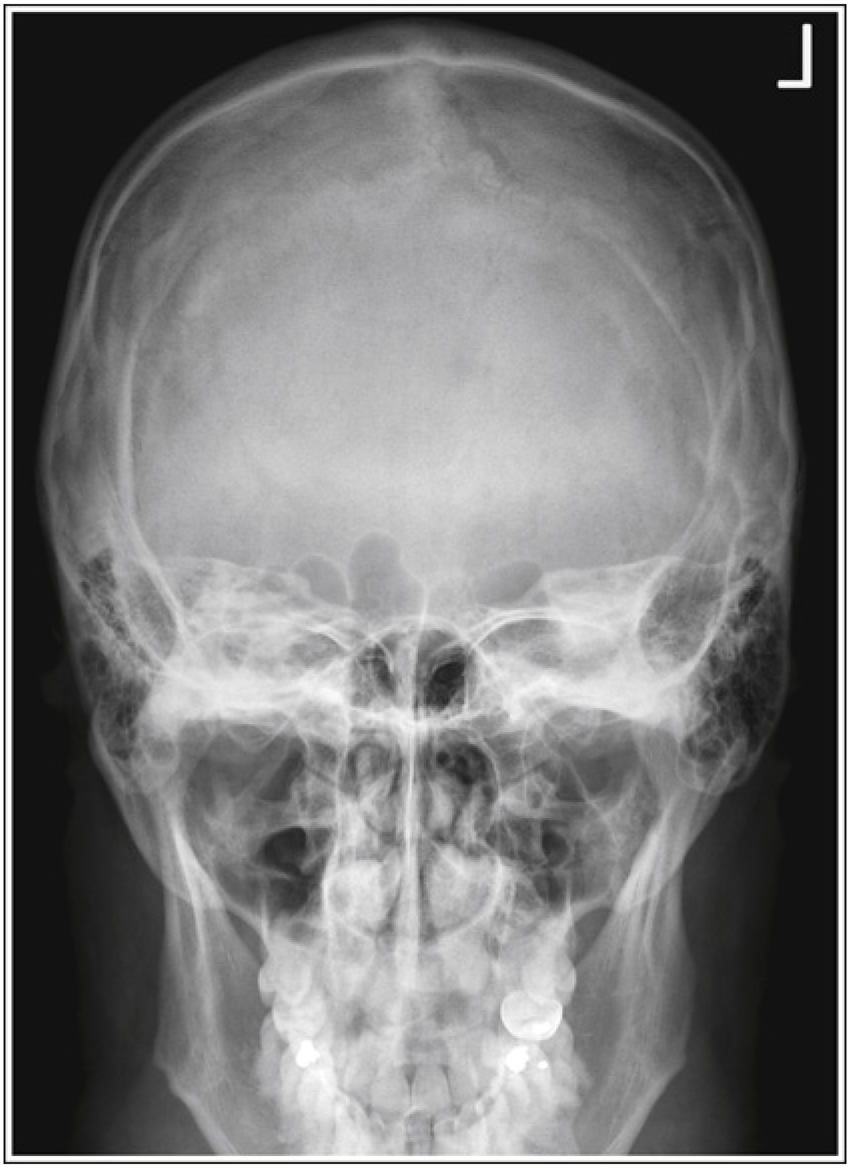


FIGURE 11.7 PA cranial projection taken with the chin tucked more than needed to bring OML perpendicular to the IR.

Mandible OML Alignment: Insufficient Chin Tucking

If the chin was insufficiently tucked to bring the OML perpendicular to the IR for the PA mandible, the petrous ridges are demonstrated inferior to the supraorbital margins, the mastoids obscure the mandibular condyles, and

the mandibular rami are foreshortened on the resulting projection (**Fig. 11.8**).

Mandible OML Alignment: Excessive Chin Tucking

If the chin is excessively tucked, placing OML at an angle with the IR for the PA mandible, the petrous ridges are demonstrated superior to the supraorbital margins, the zygomas obscure the mandibular condyles, and the mandibular rami are foreshortened on the resulting projection (**Fig. 11.9**).

Positioning for Trauma

For trauma cranial or mandibular AP projections, the patient is placed supine on the imaging table. If injury to the cervical vertebrae is suspected, do not adjust the head and chin position as described in **Table 11.3**; instead, take the projection with the head positioned as is and adjust the CR to align it parallel with the OML as demonstrated in **Fig. 11.10**. The angulation required varies according to the chin elevation provided by the cervical collar but is most often between 10 and 15 degrees caudad. Trauma projections should meet the analysis guidelines listed in **Table 11.3** for the corresponding nontrauma projections, although some features of the cranium will appear different because of the increased magnification of the structures situated farther from the IR. For example, in the AP projection the orbits are positioned farther from the IR than the lateral parietal bones, whereas in the PA projection the lateral parietal bones are farther from the IR. This difference will cause the projection to demonstrate less distance from the lateral margin of the orbits to the lateral cranial cortices on the AP than on the PA projection (see **Fig. 11.1**).

FIGURE 11.8 PA mandible projection taken with the chin insufficiently tucked to bring the OML perpendicular with the IR.

FIGURE 11.9 PA mandible projection taken with the chin tucked more than needed to bring the OML perpendicular with the IR. The mentum is also not included.

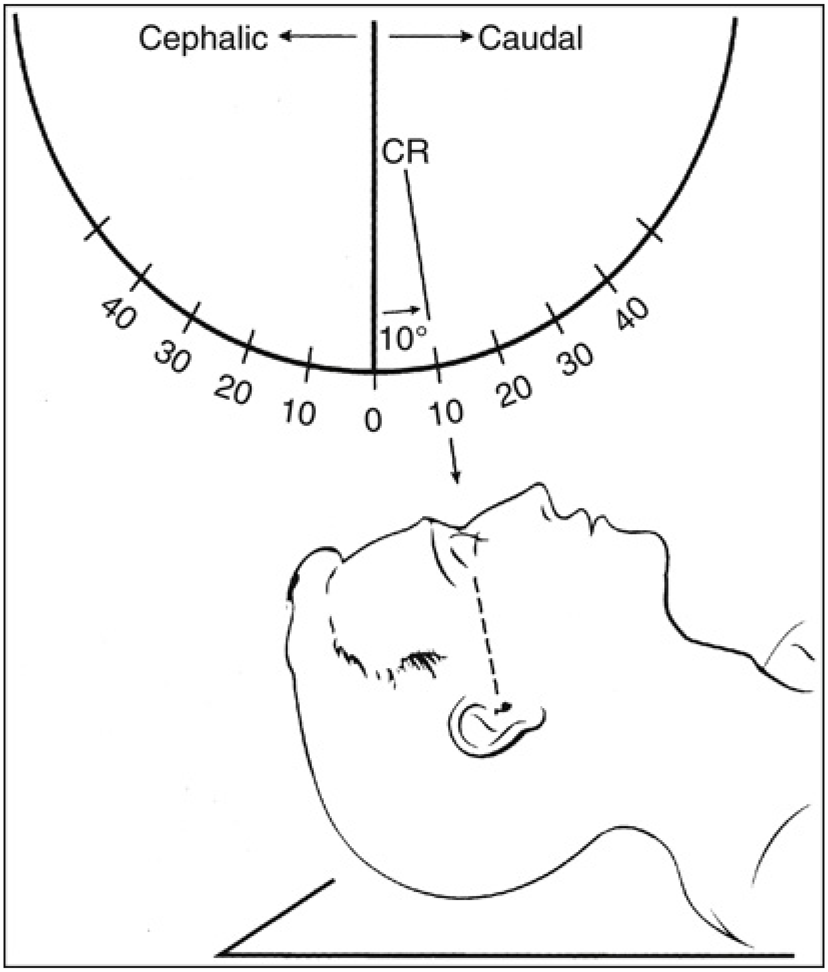


FIGURE 11.10 Determining the CR angulation to use for trauma AP cranial projection.

Trauma: Correcting for Poor CR and OML Alignment

The CR angulation determines the relationship of the petrous ridges and the supraorbital margins on a trauma AP projection. When a trauma AP cranial or mandible projection demonstrates poor supraorbital margin and petrous ridge superimposition, adjust the CR angulation in the direction that you need the orbits to move. For example, if the petrous ridges are demonstrated inferior to the supraorbital margins, the CR was angled too cephalically for the projection and should be decreased (adjusted caudally; **Figs. 11.11** and

11.12) to obtain an optimal projection. If the petrous ridges are demonstrated superior to the supraorbital margins, the CR was not angled cephalically enough and should be increased (**Fig. 11.13**).

Mandible: Jaw Positioning

To obtain a PA/AP projection of the mandible, have the patient close the jaw, with teeth and lips placed together. Failing to obtain this jaw position will result in elongated mandible rami (see **Fig. 11.12**). If the patient is unable to close the jaw and a ramus fracture is suspected, the CR can be angled slightly cephalically to offset all or some of the elongation and better align the CR perpendicular to the long axis of the rami. This cephalic CR angulation will cause the mandibular condyles to superimpose over more of the mastoid processes.

FIGURE 11.11 Trauma AP cranial projection taken with the CR angled too cephalically.

FIGURE 11.12 Trauma AP mandible projection taken with the CR angled too cephalically and the mouth open.

FIGURE 11.13 Trauma AP cranial projection taken with the CR angled too caudally or the chin tucked too much.

FIGURE 11.14 PA cranial projection taken with the head tilted.

Head Tilting and Midsagittal Plane Alignment

Aligning the head's midsagittal plane with the long axis of the IR ensures that the bony nasal septum is aligned with the long axis of the exposure field and the cranium and mandible are demonstrated without tilting. Slight head tilting may not result in noticeable change with any of the anatomic relationships for this position, although as tilting increases it causes the CR

(and beam divergence) to align incorrectly with the anatomical structures and may result in rotation (**Fig. 11.14**). It also prevents tight collimation.

PA or AP Analysis Practice

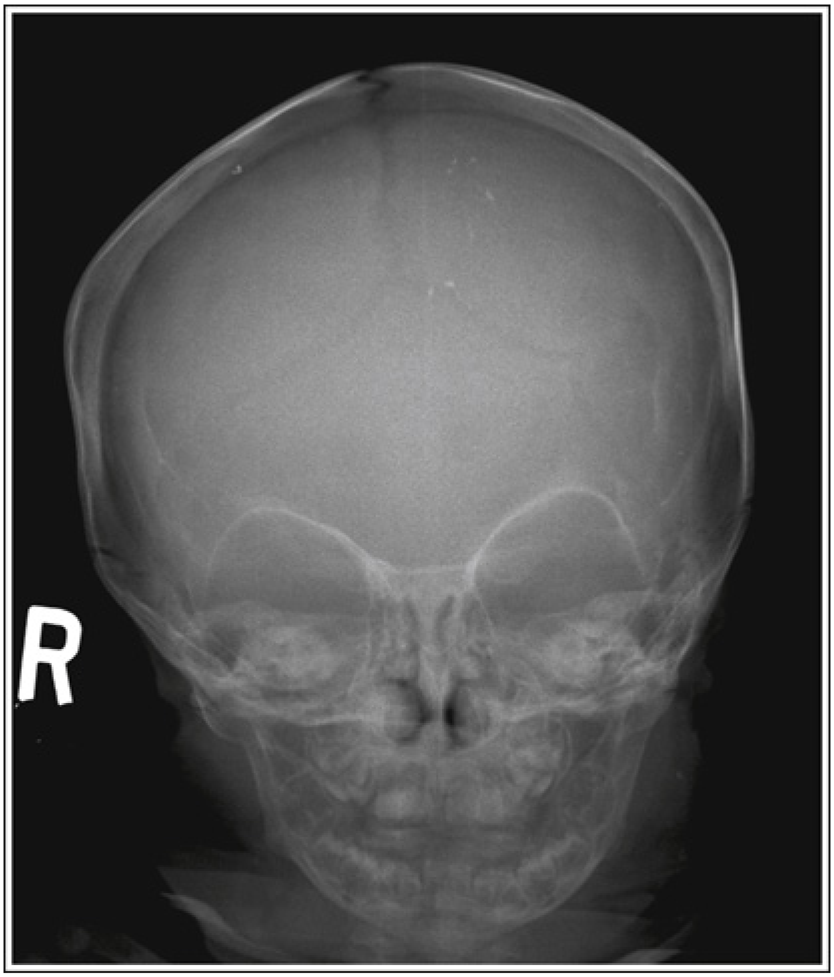


IMAGE 11.1

AP CRANIUM PROJECTION.

Analysis

The distances from the lateral orbital margins to the lateral cranial cortices on the right side are greater than the same distances on the left side. The face was rotated toward the left side. The petrous ridges are demonstrated inferior to the supraorbital margins; the chin was not tucked enough to position the OML perpendicular to the IR.

Correction

Rotate the face toward the right side until the midsagittal plane is aligned perpendicular to the IR. Tuck the chin until the OML is aligned perpendicular to the IR or adjust the CR angulation caudally.

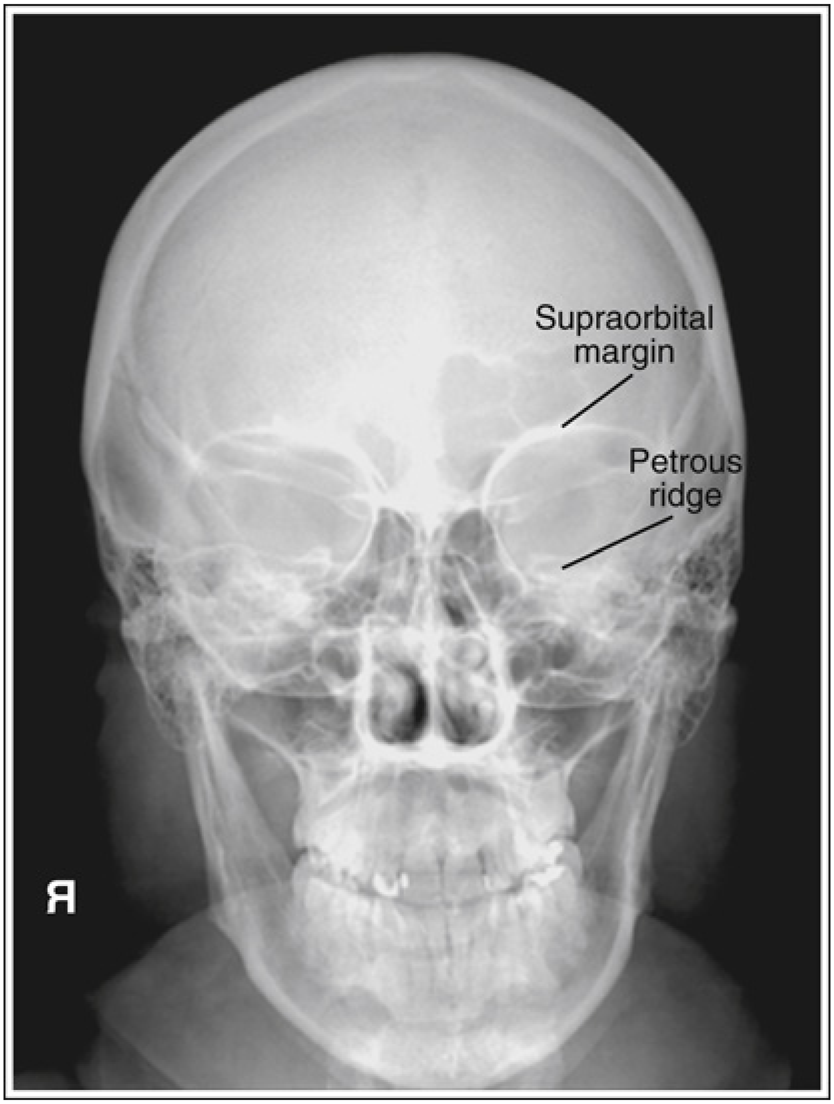


IMAGE 11.2

PA CRANIUM PROJECTION.

Analysis

The petrous ridges are demonstrated inferior to the superior orbital margins, and the dorsum sellae and anterior clinoids are demonstrated within the

ethmoid sinuses. The chin was not tucked enough to position the OML perpendicular to the IR.

Correction

Tuck the chin until the OML is aligned perpendicular to the IR or move it the full distance demonstrated between the petrous ridges and the supraorbital margins.

IMAGE 11.3

AP CRANIUM PROJECTION.

Analysis

The petrous ridges, demonstrated superior to the supraorbital margins in the internal acoustic meatus, are obscured. The chin was tucked more than

needed to position the OML perpendicular to the IR.

Correction

Extend the neck, moving the chin away from the thorax until the OML is aligned perpendicular to the IR or move it the full distance demonstrated between the petrous ridges and the supraorbital margins.

IMAGE 11.4

PA CRANIUM PROJECTION.

Analysis

The petrous ridges are demonstrated superior to the supraorbital margins and the internal acoustic meatus are obscured. The chin was tucked more

than needed to position the OML perpendicular to the IR.

Correction

Extend the neck, moving the chin away from the thorax until the OML is aligned perpendicular to the IR or move it the full distance demonstrated between the petrous ridges and the supraorbital margins.

IMAGE 11.5

PA MANDIBLE PROJECTION.

Analysis

The petrous ridges are demonstrated inferior to the superior orbital margins and the dorsum sellae and anterior clinoids are demonstrated within the ethmoid sinuses. The chin was not tucked enough to position the OML perpendicular to the IR.

Correction

Tuck the chin until the OML is aligned perpendicular to the IR or move it the full distance demonstrated between the petrous ridges and the supraorbital margins.

Cranium, Facial Bones, and Sinuses: PA or AP Axial Projection (Caldwell Method)

See **Table 11.4** and Figs. **11.15–11.18**.

Cranium Rotation

Cranial rotation is present on an AP axial projection if the distance from the lateral orbital margin to the lateral cranial cortex on one side is greater than that on the other side (**Fig. 11.19**). The face was rotated away from the side demonstrating the greater distance (see **Fig. 11.22**).

OML Alignment: Insufficient Chin Tuck

Poor OML and CR alignment can be detected on the PA axial by evaluating the relationship of the petrous ridges and the orbits. If the chin was not adequately tucked to bring the OML perpendicular to the IR, or if the OML was adequately positioned but the CR was angled more than 15 degrees caudally, the petrous ridges are demonstrated inferior to the infraorbital margins (**Fig. 11.20**).

For a patient who is unable to tuck the chin adequately to position the OML perpendicular to the IR, the CR angulation may be adjusted to compensate. Instruct the patient to tuck the chin to position the OML as close as possible to perpendicular to the IR. Next, angle the CR parallel with the OML and then adjust the CR 15 degrees caudally for the PA axial projection and 15 degrees cephalically for the AP axial projection (**Fig. 11.21**).

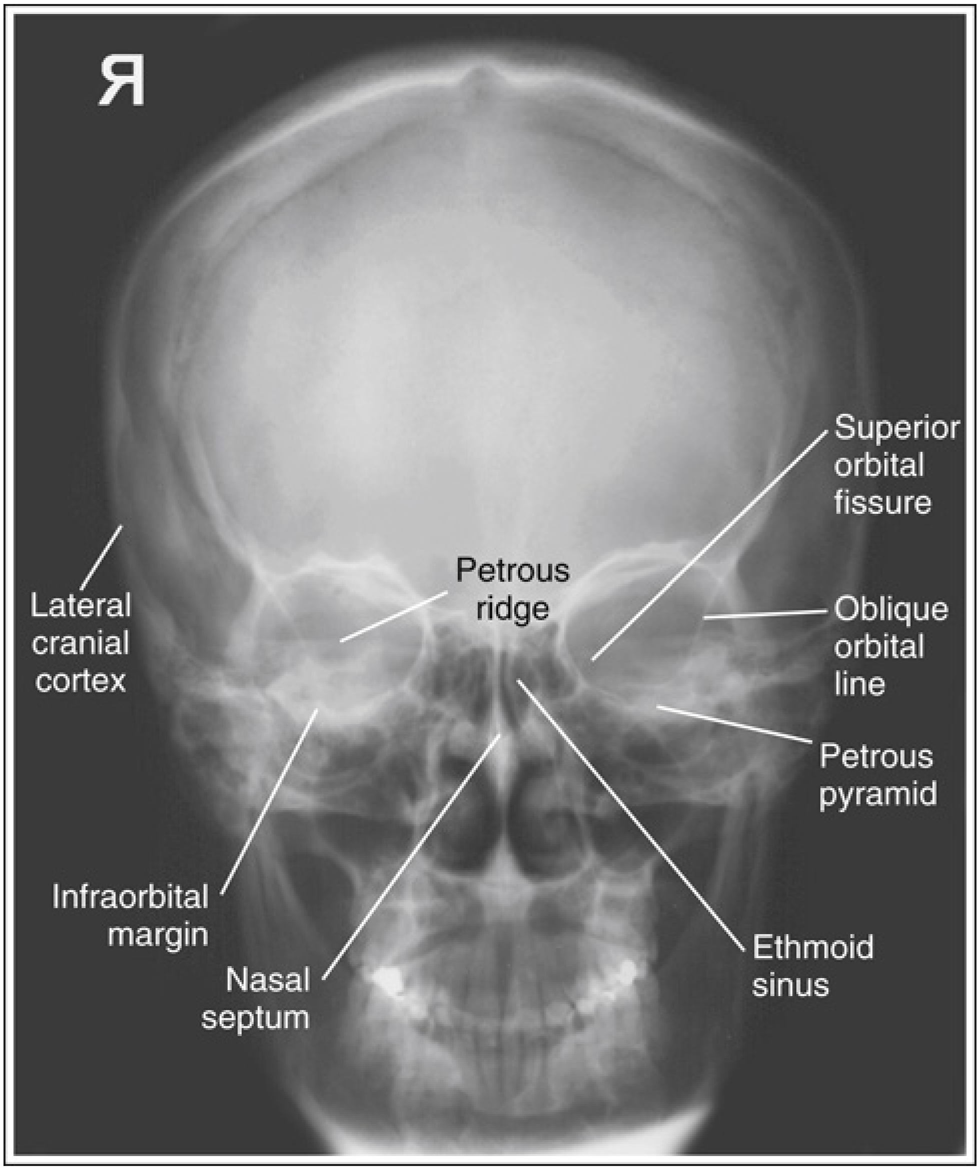


FIGURE 11.15 PA axial cranial projection (Caldwell method) with accurate positioning.

TABLE 11.4

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor; *OML*, orbitomeatal line; *PA*, posteroanterior.

FIGURE 11.16

AP AXIAL CRANIAL PROJECTION (CALDWELL METHOD) WITH ACCURATE POSITIONING.

FIGURE 11.17 PA axial sinus/facial bones projection (Caldwell method) with accurate positioning.

OML Alignment: Excessive Chin Tuck

If the chin was tucked more than needed to bring the OML perpendicular to the IR, or if the OML was adequately positioned but the CR was angled less than 15 degrees caudally, the petrous ridges and pyramids are demonstrated in the upper half of the orbits (**Fig. 11.22**).

Trauma AP Axial Projection (Caldwell Method): CR Angled Too Cephalically

For a trauma AP axial projection taken on a patient who cannot adjust the head to accurately align the OML, begin by angling the CR parallel with the OML, as shown in **Fig. 11.21**. The angulation required to do this varies

according to the chin elevation provided by the cervical collar, but is most often between 10 and 15 degrees caudad. From this angulation, adjust the CR 15 degrees cephalad (a cephalic angulation is used instead of a caudal angle because the patient is now in an AP projection) to align the angle 15 degrees from the OML, as shown in **Fig. 11.21**. For example, if a 10-degree caudal angle were needed to position the CR parallel with the OML, a 5-degree cephalic angulation would be required for the AP axial projection, 15 degrees cephalad from the OML.

For the trauma AP axial projection, the CR angulation determines the relationship of the petrous ridges and the orbits. For an AP axial projection that demonstrates a poor petrous ridge and orbital relationship, adjust the CR angulation in the direction in which you want the orbits to move. If the petrous ridges are demonstrated inferior to the infraorbital margins, the CR was angled too cephalically and will need to be decreased (**Fig. 11.23**).

Trauma AP Axial Projection (Caldwell Method): CR Angled Too Caudally

If the petrous ridges are demonstrated in the superior half of the orbits, the CR was not angled cephalically enough and will need to be increased (**Fig. 11.24**).

Head Tilting and Midsagittal Plane Alignment

Head tilting causes the CR (and beam divergence) to align incorrectly with the anatomical structures and may result in a rotation. It also prevents tight collimation (**Fig. 11.25**).

FIGURE 11.18 Proper patient positioning for PA axial cranial projection (Caldwell method).

FIGURE 11.19 PA axial cranial projection (Caldwell method) taken with the face rotated toward the left side.

FIGURE 11.20 PA axial cranial projection (Caldwell method) taken with insufficient chin tuck or with the CR angled too caudally.

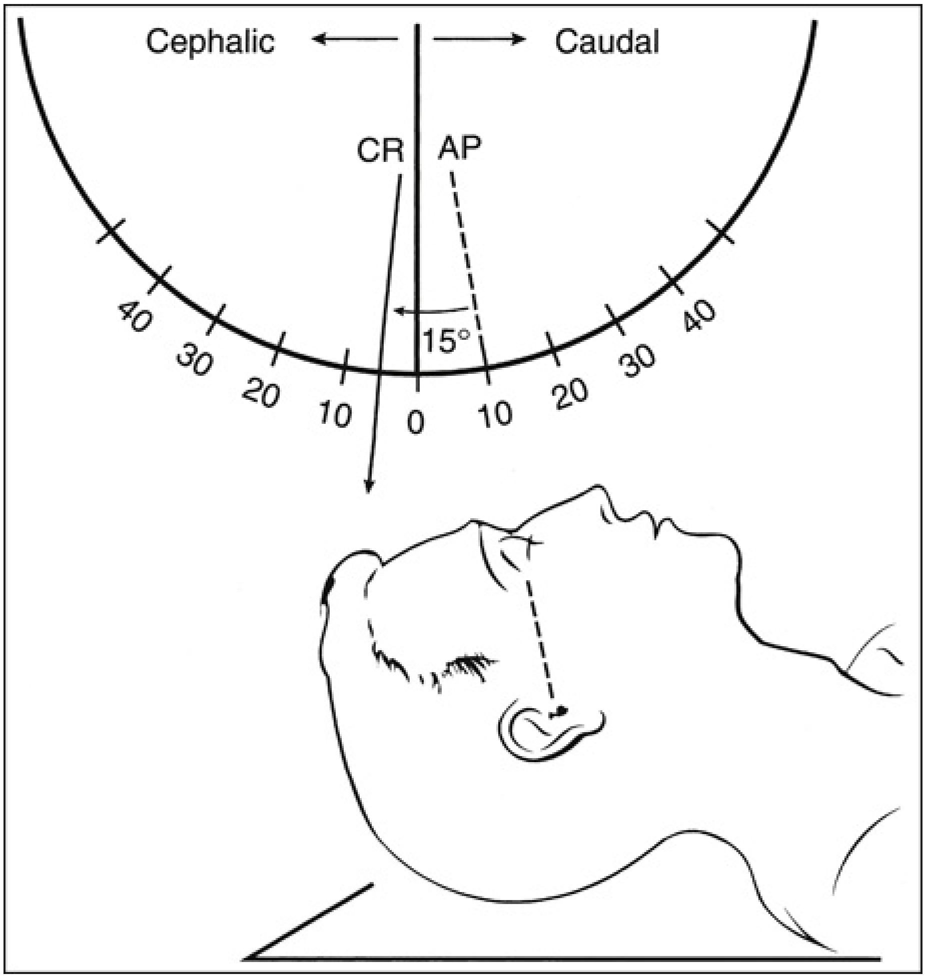


FIGURE 11.21 Determining central ray *(CR)* angulation for trauma AP axial cranial projection (Caldwell method).

FIGURE 11.22 PA axial cranial projection (Caldwell method) taken with the face rotated toward the right side and the chin tucked more than needed to bring the OML perpendicular to the IR or with the CR angled too cephalically.

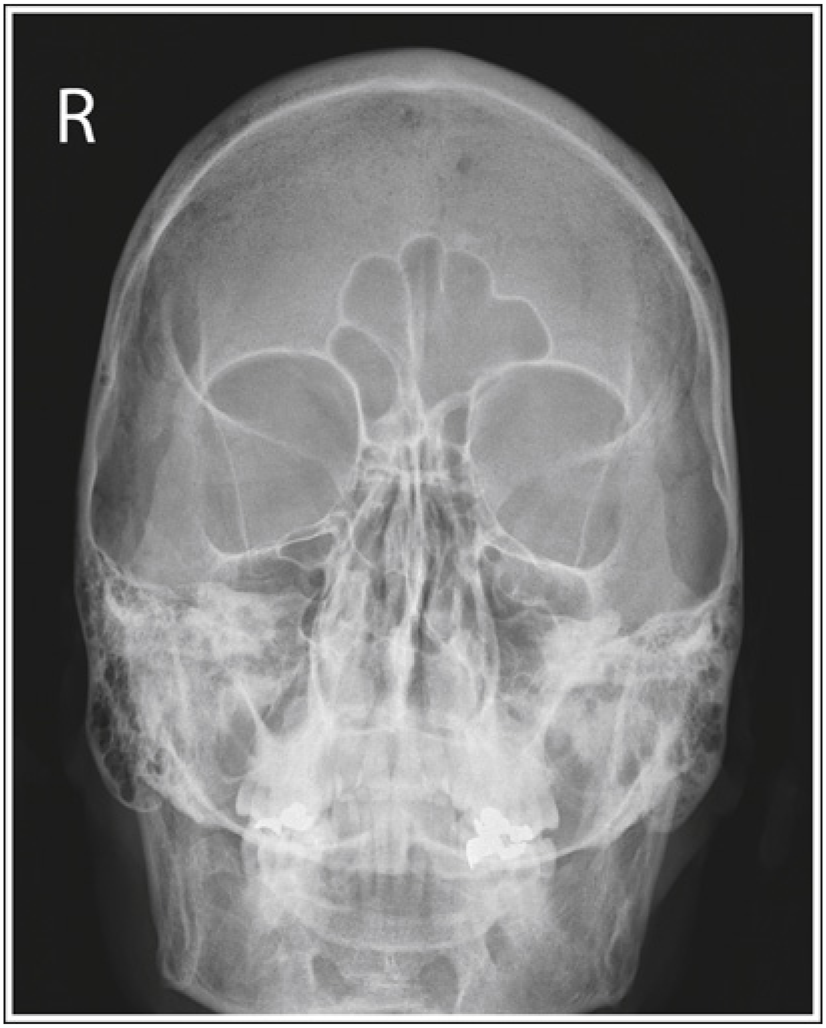


FIGURE 11.23 AP axial cranial projection (Caldwell method) taken with the CR angled too cephalically or the chin tucked less than needed to bring the OML perpendicular to the IR.

FIGURE 11.24 AP axial cranial projection (Caldwell method) taken with the CR angled too caudally or the chin tucked more than needed to bring the OML perpendicular to the IR.

FIGURE 11.25 PA axial projection (Caldwell method) obtained with the head tilted.

PA/AP Axial Analysis Practice

IMAGE 11.6

PA AXIAL CRANIUM PROJECTION.

Analysis

The distances from the lateral orbital margins to the lateral cranial cortices and from the crista galli to the lateral cranial cortex are greater on the left side than on the right side. The face was rotated toward the right side. The

petrous ridges are demonstrated inferior to the infraorbital margins. The chin was not tucked enough to position the OML perpendicular to the IR.

Correction

Rotate the face toward the left side and tuck the chin to bring the OML perpendicular to the IR.

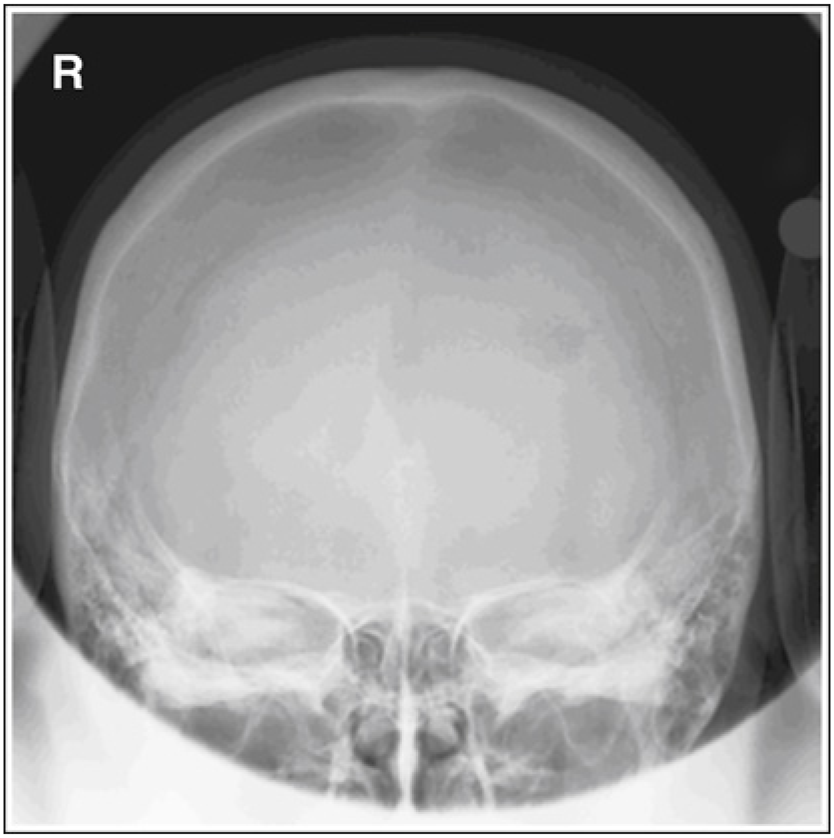


IMAGE 11.7

AP AXIAL CRANIUM PROJECTION.

Analysis

The petrous ridges and pyramids are demonstrated in the superior half of the orbits. The chin was tucked more than needed to position the OML perpendicular to the IR or the CR was angled too caudally.

Correction

Elevate the chin until the OML is perpendicular to the IR or adjust the CR angulation cephalically.

Cranium and Mandible: AP Axial Projection (Towne Method)

See **Table 11.5** and Figs. **11.26–11.28**.

Cranium Rotation

Head rotation is demonstrated on an AP axial projection if the distance from the posterior clinoid process and dorsum sellae to the lateral border of the foramen magnum is greater on one side and the distance from the mandibular neck to the cervical vertebrae is greater on one side than on the other side. The face was rotated toward the side demonstrating the least distance from the posterior clinoid process and dorsum sellae to the lateral foramen magnum and from the mandibular neck to the cervical vertebrae (**Fig. 11.29**).

OML Alignment: Insufficient Chin Tuck

If a patient tucked the chin less than needed to position the OML perpendicular to the IR, the dorsum sellae will be demonstrated superior to the foramen magnum (**Figs. 11.30** and **11.31**).

OML Alignment: Excessive Chin Tuck

If the patient tucked the chin more than needed to align the OML perpendicular to the IR, the dorsum sellae will be foreshortened and will be superimposed over the atlas's posterior arch (**Fig. 11.32**).

OML Alignment: Trauma AP Axial Projection

In a patient who is unable to adequately tuck the chin to position the OML perpendicular to the IR because of cervical trauma or stiffness, the CR angulation may be adjusted to compensate. Instruct the patient to tuck the chin to position the OML as close as possible to perpendicular to the IR. Next, angle the CR parallel with the OML and then adjust the CR 30 degrees caudally to obtain an AP axial cranium and petromastoid projection (**Fig. 11.33**) and 35 to 40 degrees caudally from the angle obtained to obtain an AP axial mandible projection. The angle used for this projection should not exceed 45 degrees or excessive distortion will result.

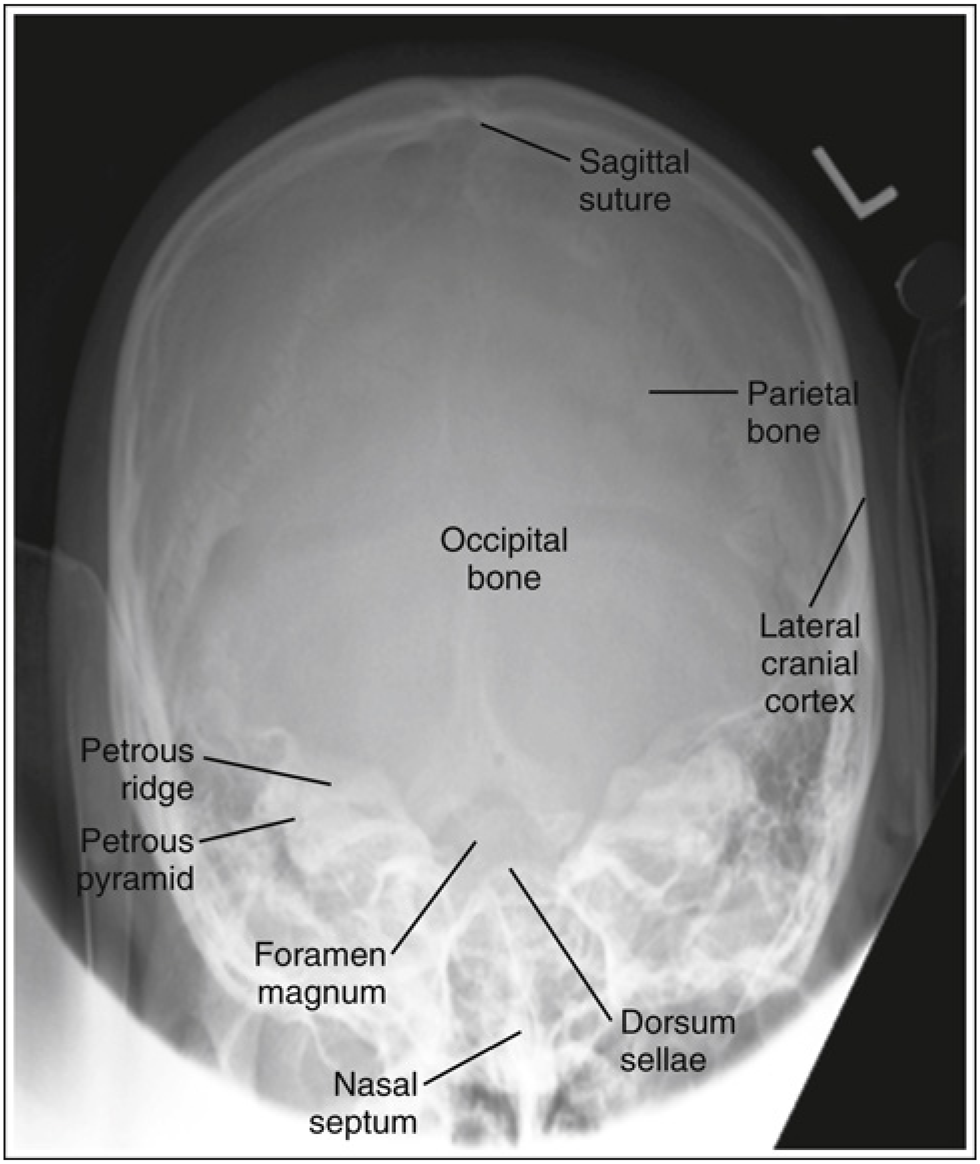


FIGURE 11.26 AP axial (Towne method) cranial and mastoid projection with accurate positioning.

TABLE 11.5

AP, Anteroposterior; *CR*, central ray; *EAM*, external auditory meatus; *IR*, image receptor; *OML*, orbitomeatal line.

Cranial Tilting

Head tilting is demonstrated on an AP axial projection when the midsagittal plane is not aligned with long axis of the IR. Because the CR is not aligned with the midsagittal plane with head tilt, the resulting projection also demonstrates rotation. With head rotation the distance from the lateral border of the foramen magnum to the lateral border of the cranium is greater on one side than on the other. Head tilting, though, will also demonstrate the petrous ridges at different transverse levels, while head rotation will not. The head is tilted toward the side demonstrating the inferior petrous ridge and the side demonstrating the greatest distance from the foramen magnum to the lateral border of the cranium (**Fig. 11.34**).

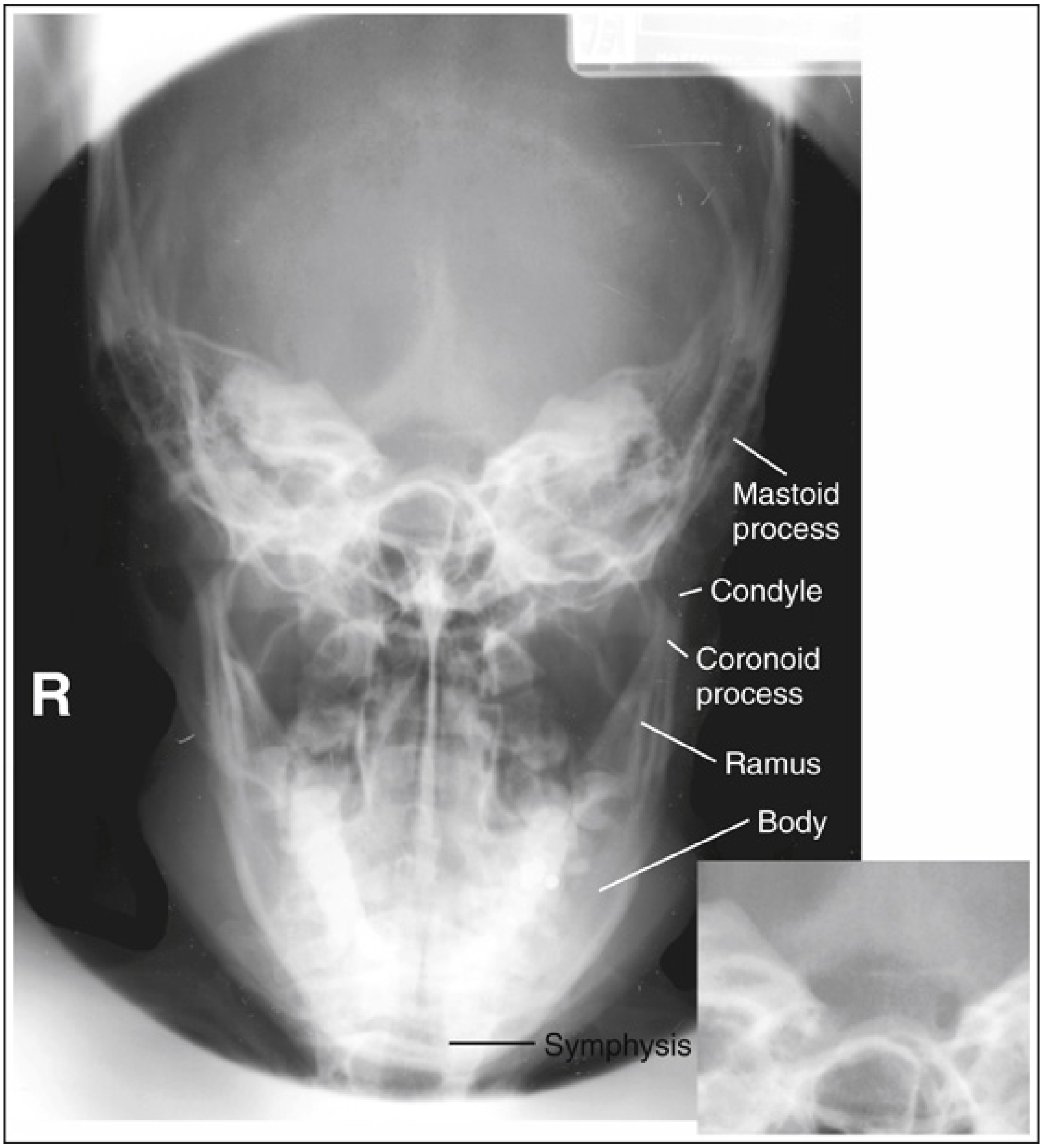


FIGURE 11.27 AP axial (Towne method) mandible projection with accurate positioning.

FIGURE 11.28 Proper patient positioning for AP axial cranial projection (Towne method).

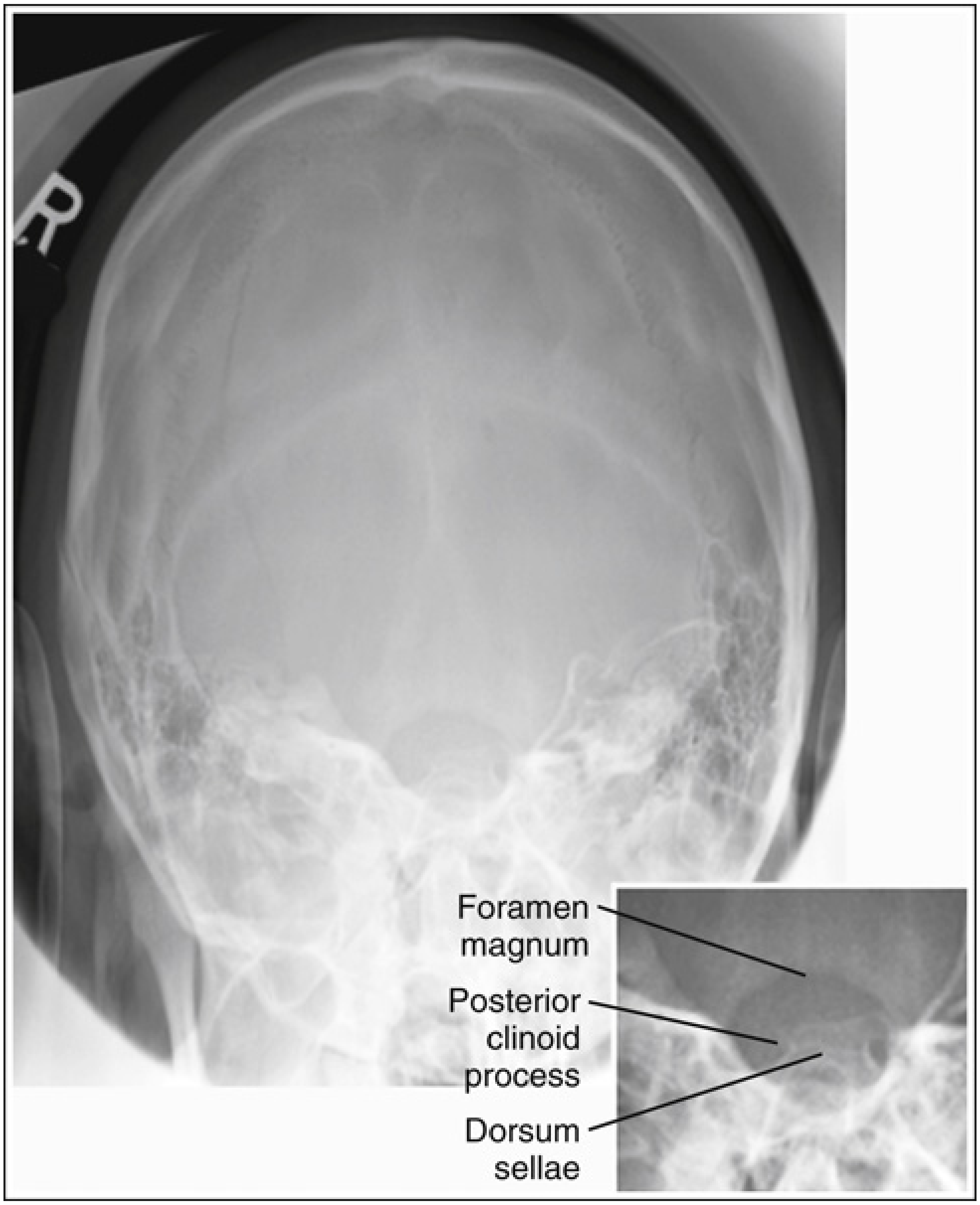


FIGURE 11.29 AP axial cranial projection (Towne method) taken with the face rotated toward the left side.

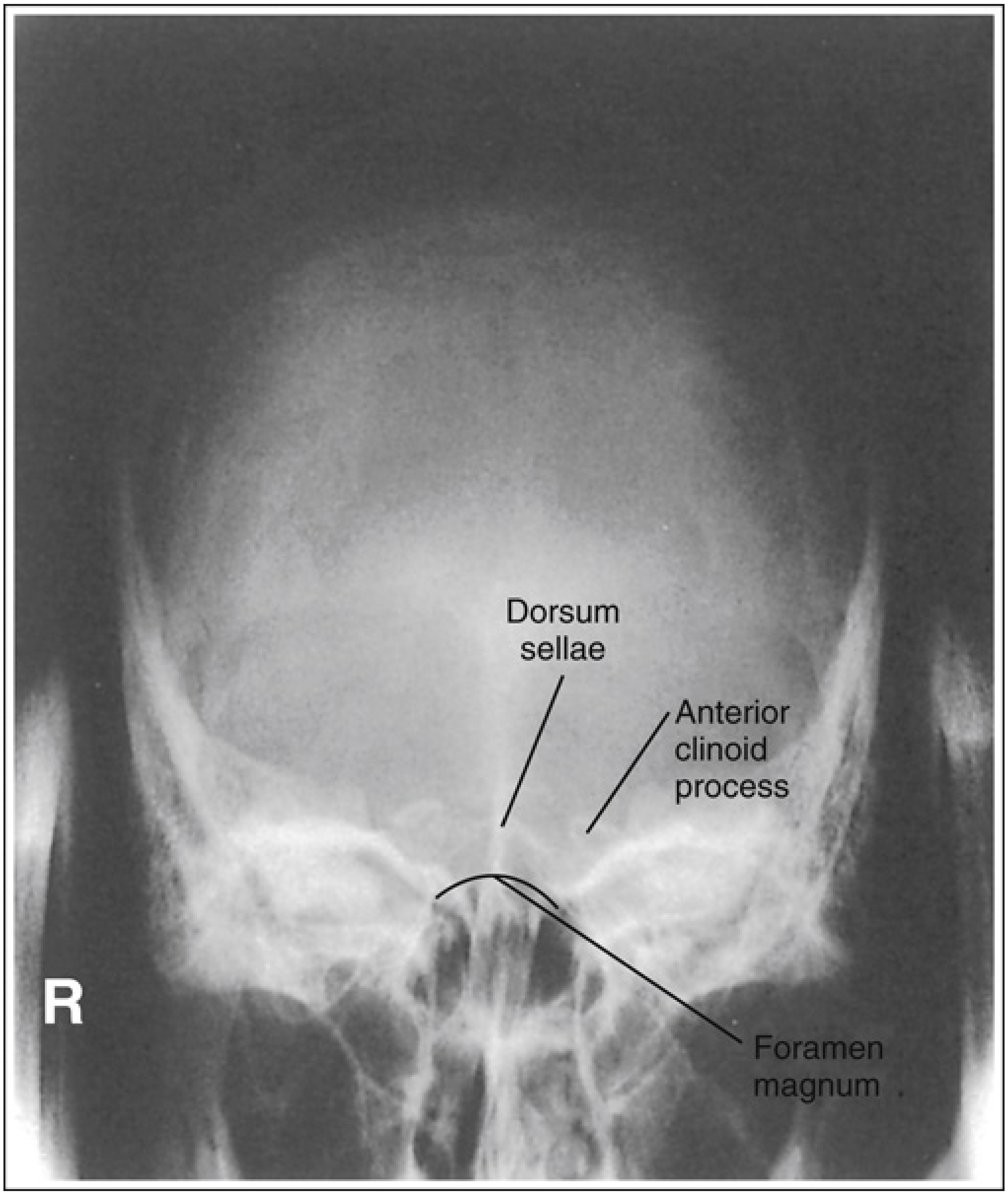


FIGURE 11.30 AP axial cranial projection (Towne method) taken with the chin tucked less than needed to position the OML perpendicular to the IR or with the CR angled too cephalically.

FIGURE 11.31 AP axial mandible projection (Towne method) taken with the chin tucked less than needed to position the OML perpendicular to the IR or with the CR angled too cephalically.

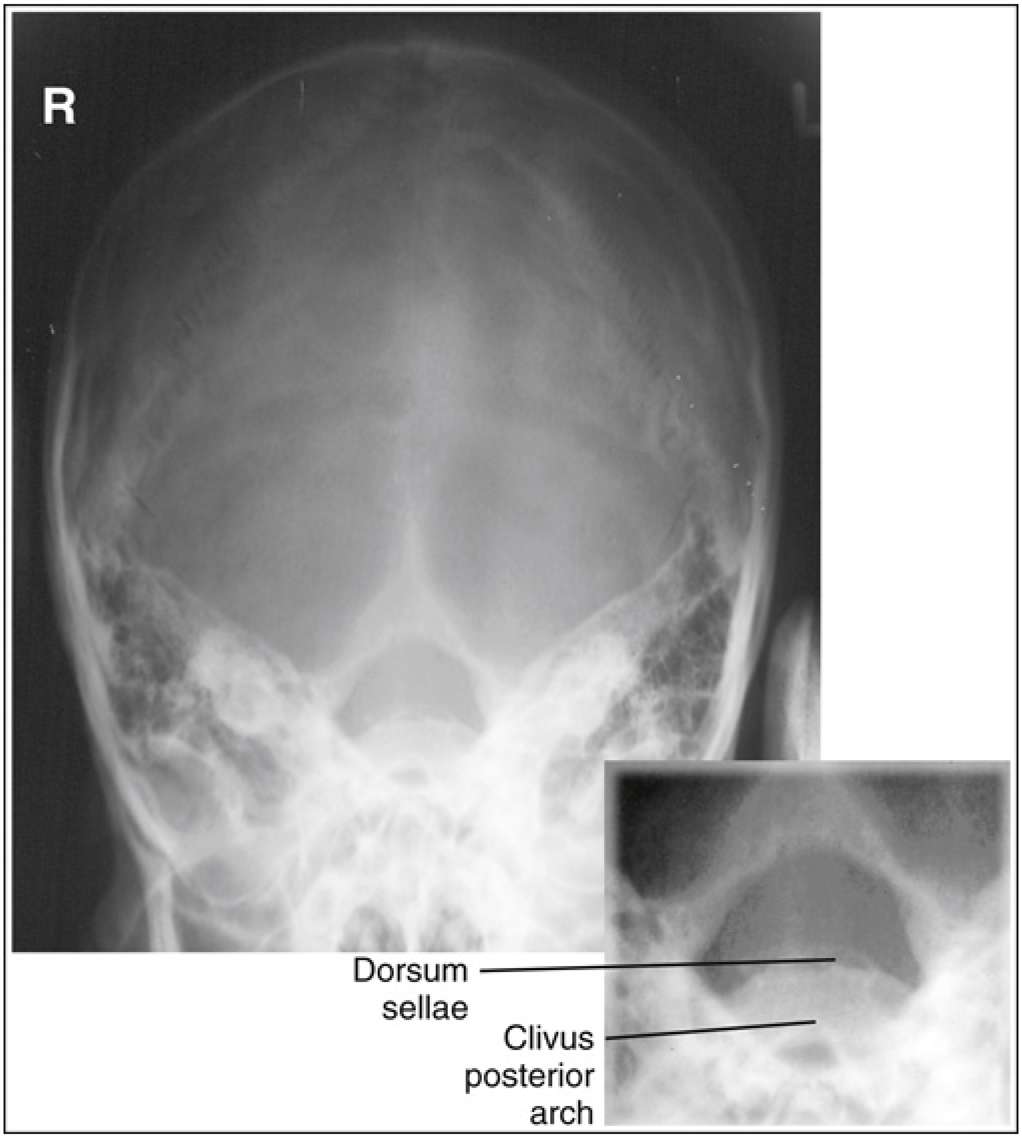


FIGURE 11.32 AP axial cranial projection (Towne method) taken with the chin tucked more than needed to position the OML perpendicular to the IR or with the CR angled too caudally.

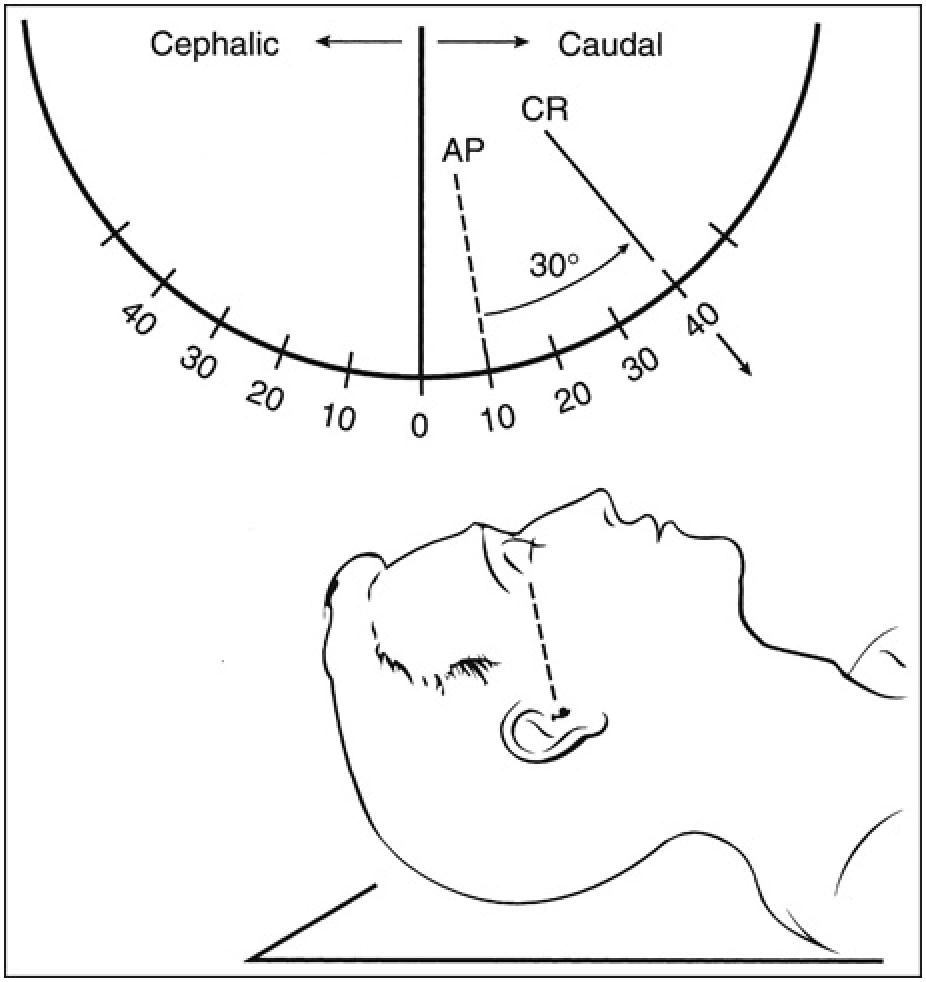


FIGURE 11.33 Determine central ray *(CR)* angulation for AP axial cranial projection (Towne method) in a trauma patient.

FIGURE 11.34 AP axial cranial projection (Towne method) taken with the head tilted and the face rotated toward the left side.

AP Axial (Towne Method) Analysis Practice

IMAGE 11.8

AP AXIAL MANDIBLE PROJECTION.

Analysis

The dorsum sellae and anterior clinoids are demonstrated superior to the foramen magnum. Either the chin was not tucked enough or the CR was not

angled caudally enough to form a 30-degree angle with the OML.

Correction

Tuck the chin until the OML is perpendicular to the IR. If the patient is unable to tuck the chin any further, leave the chin positioned as is and adjust the CR angulation caudally the needed amount.

Cranium, Facial Bones, Nasal Bones, and Sinuses: Lateral Projection

See **Table 11.6** and Figs. **11.35–11.39**.

Air-Fluid Levels in Sinus Cavities

To demonstrate air-fluid levels within the sinus cavities, the lateral projection must be taken in an upright position with a horizontal CR. In this position the thick, gelatin-like sinus fluid settles to the lowest position, creating an air-fluid line that shows the reviewer the amount of fluid present.

Cranium Rotation

Accurate positioning of the head's midsagittal plane is essential to prevent rotation of the cranium, facial bones, sinuses, and nasal bones. If the head was not adequately turned to position the midsagittal plane parallel with the IR, rotation results. Rotation causes distortion of the sella turcica and situates one of the mandibular rami, greater wings of the sphenoid, external acoustic canals, zygomatic bones, and anterior cranial cortices anterior to the other on a lateral projection (**Figs. 11.40** and **11.41**). Because the two sides of the cranium are mirror images, it is very difficult to determine which way the face was rotated when studying lateral projections with poor

positioning. Paying close attention to initial positioning may give you an idea as to which way the patient has a tendency to lean. Routinely, patients tend to rotate their faces and lean the tops of their heads toward the IR.

Cranium Tilting

The lateral projection is obtained without head tilting when the interpupillary line (IPL) is aligned perpendicular with the IR. If the head was tilted toward or away from the IR, preventing the midsagittal plane from aligning parallel with the IR or the IPL from aligning perpendicular to the IR, tilting of the cranium, facial bones, sinuses, and nasal bones results. Tilting can be distinguished from rotation on lateral projections by studying the superimposition of the orbital roofs, the greater wings of the sphenoid, the external acoustic canals, the zygomatic bones, and the inferior cranial cortices. If the head was tilted, one of each corresponding structure is demonstrated superior to the other. The direction of the head tilt, toward or away from the IR, can be determined by evaluating the degree of atlas (C1) vertebral foramen visualization. If the top of the head is tilted toward the IR, the foramen will not be visualized, and if the tip of the head is tilted away from the IR, the foramen will be seen (**Fig. 11.42**).

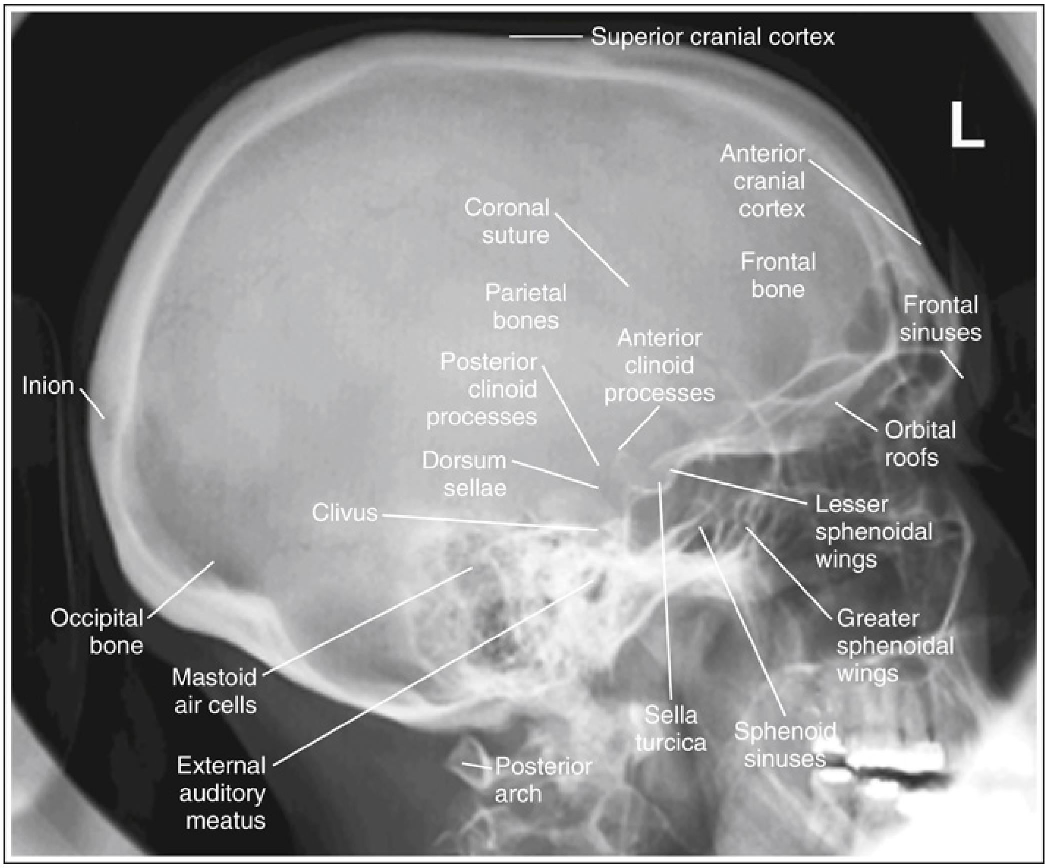


FIGURE 11.35 Lateral cranial projection with accurate positioning.

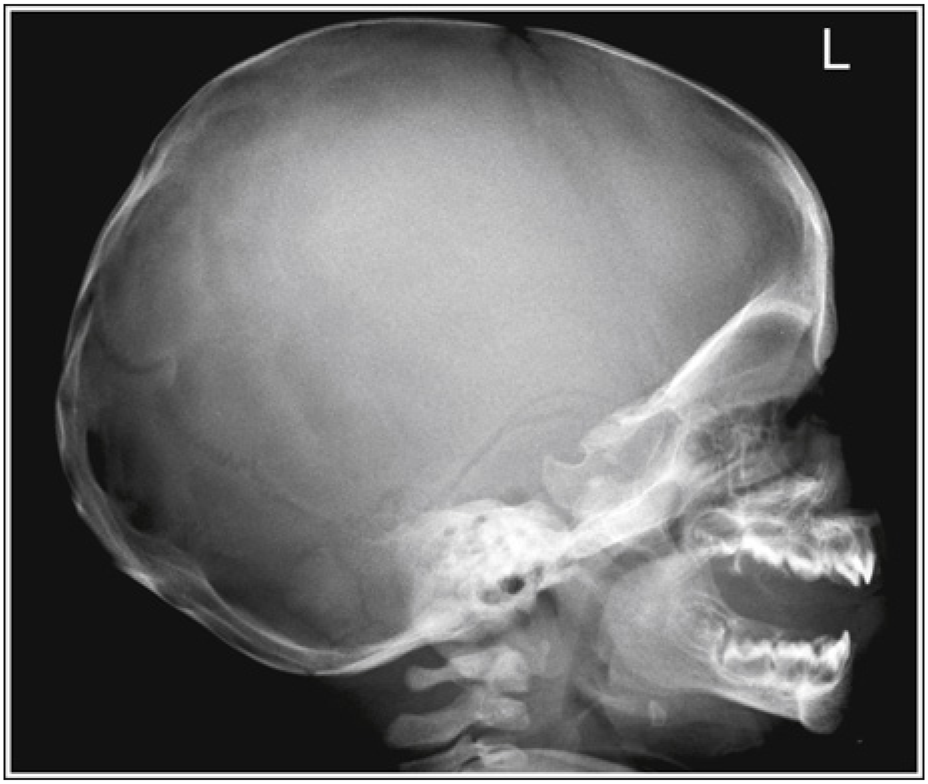


FIGURE 11.36

PEDIATRIC LATERAL CRANIAL PROJECTION WITH ACCURATE POSITIONING.

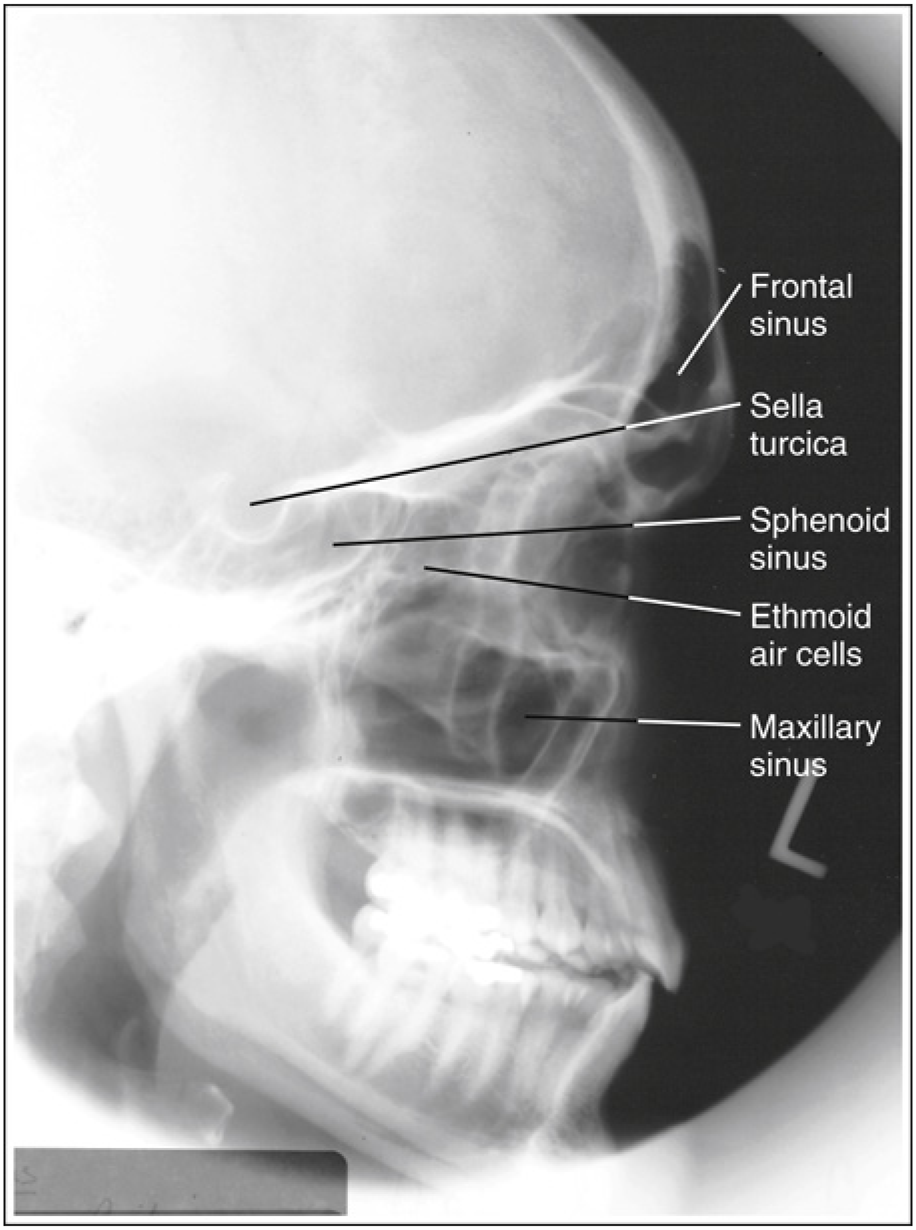


FIGURE 11.37

LATERAL FACIAL BONE AND SINUS PROJECTION WITH ACCURATE POSITIONING.

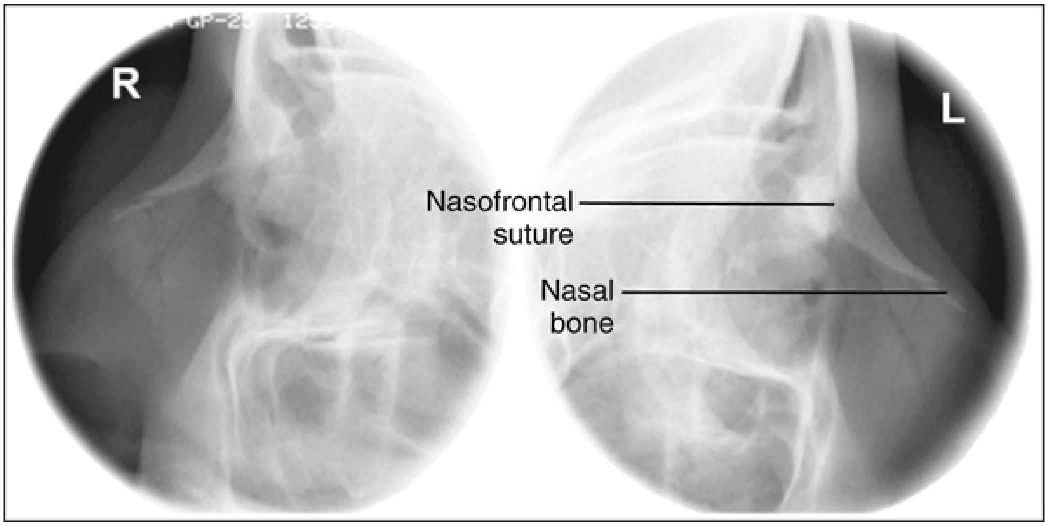


FIGURE 11.38 Lateral nasal bone projection with accurate positioning.

FIGURE 11.39 Proper patient positioning for lateral cranial projection.

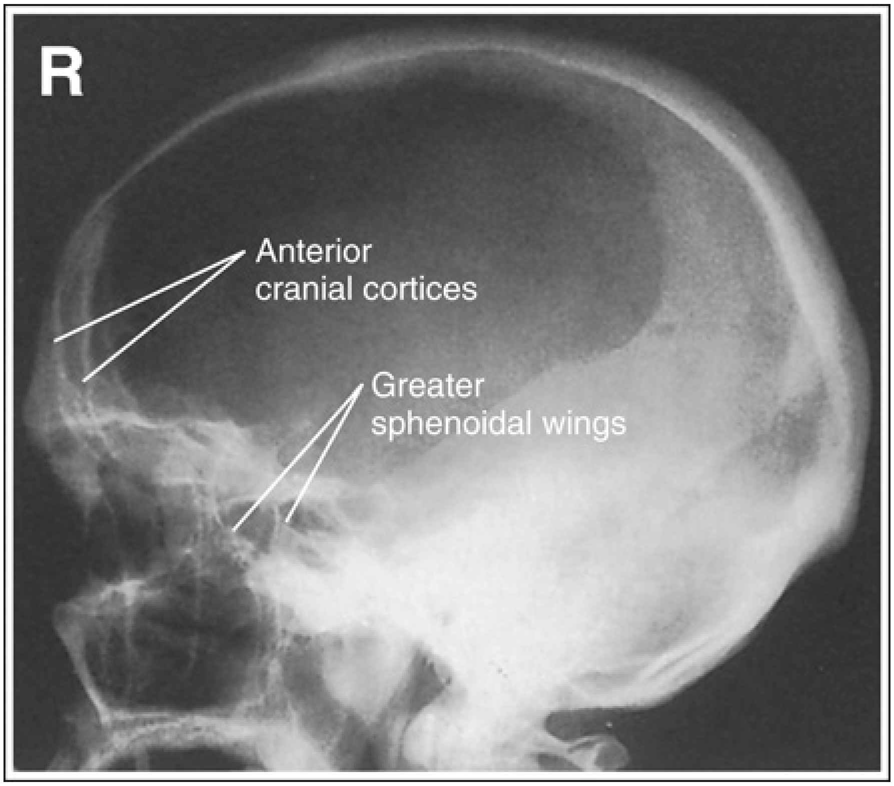


FIGURE 11.40 Lateral cranial projection taken with the head rotated.

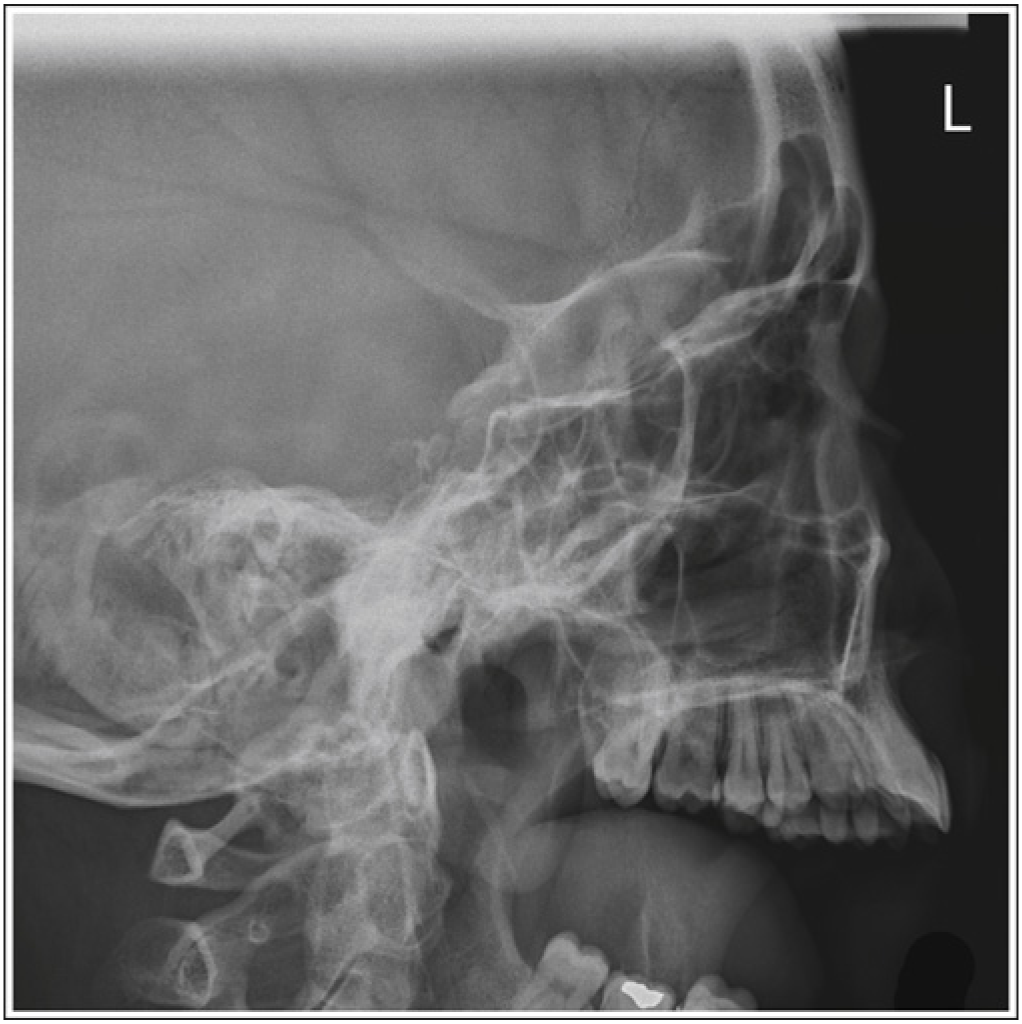


FIGURE 11.41 Lateral sinuses projection obtained with head rotation.

FIGURE 11.42 Lateral cranial projection taken with top of the head tilted away from the IR. The top of the cranium is also not included.

TABLE 11.6

CR, Central ray; *EAM*, external auditory meatus; *IOML*, infraorbitomeatal line; *IPL*, interpupillary line; *IR*, image receptor; *PA*, posteroanterior.

Positioning for Trauma

A trauma lateral projection is accomplished by placing the IR and grid against the lateral cranium and directing a horizontal CR to a point 2 inches (5 cm) superior to the external auditory meatus (EAM) (**Fig. 11.43**). For a patient whose head position can be manipulated, elevate the occiput on a radiolucent sponge and adjust the head as indicated for the nontrauma lateral projection. If a cervical vertebral injury is suspected, do not adjust the head until it has been cleared by the radiologist or take the projection with the head positioned as is and the IR positioned 1 inch (2.5 cm) below the occipital bone.

FIGURE 11.43 Proper patient positioning for the trauma lateral cranial projection.

Lateral Projection Analysis Practice

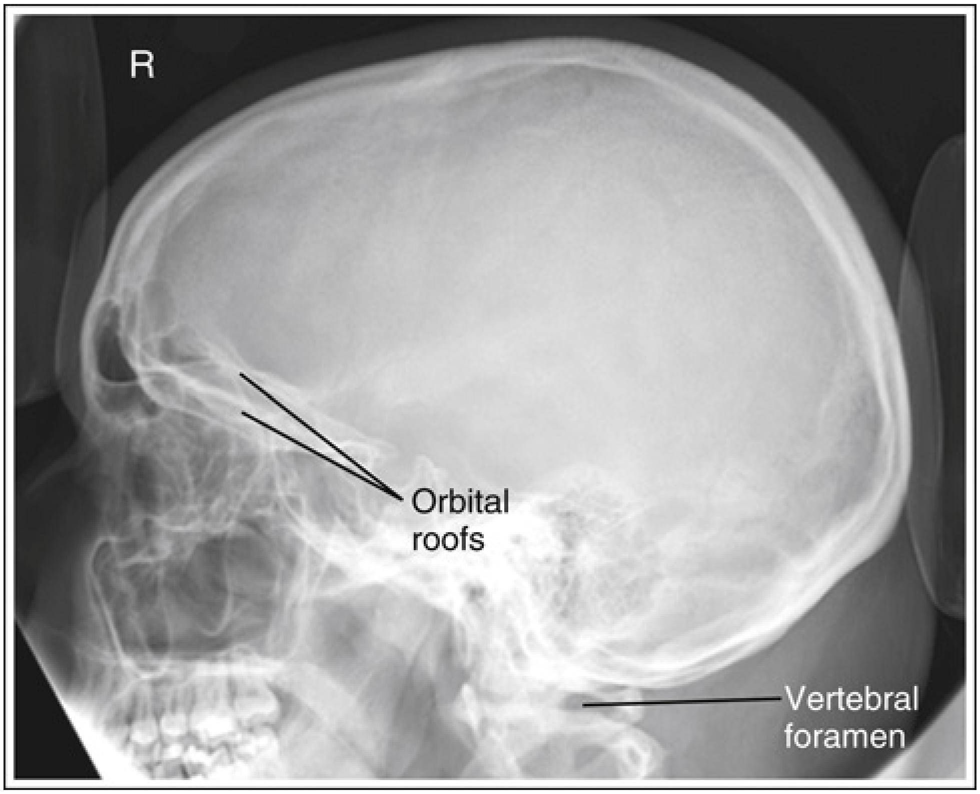


IMAGE 11.9

LATERAL CRANIUM PROJECTION.

Analysis

The orbital roofs, EAMs, and inferior cranial cortices are demonstrated without superimposition. One of each corresponding structure is demonstrated superior to the other and the atlas's vertebral foramen is visualized. The head was tilted away from the IR.

Correction

Position the cranium's midsagittal plane parallel with the IR and the IPL perpendicular to the IR.

Cranium, Mandible, and Sinuses: SMV Projection (Schueller Method)

See **Table 11.7** and Figs. **11.44**–**11.46**.

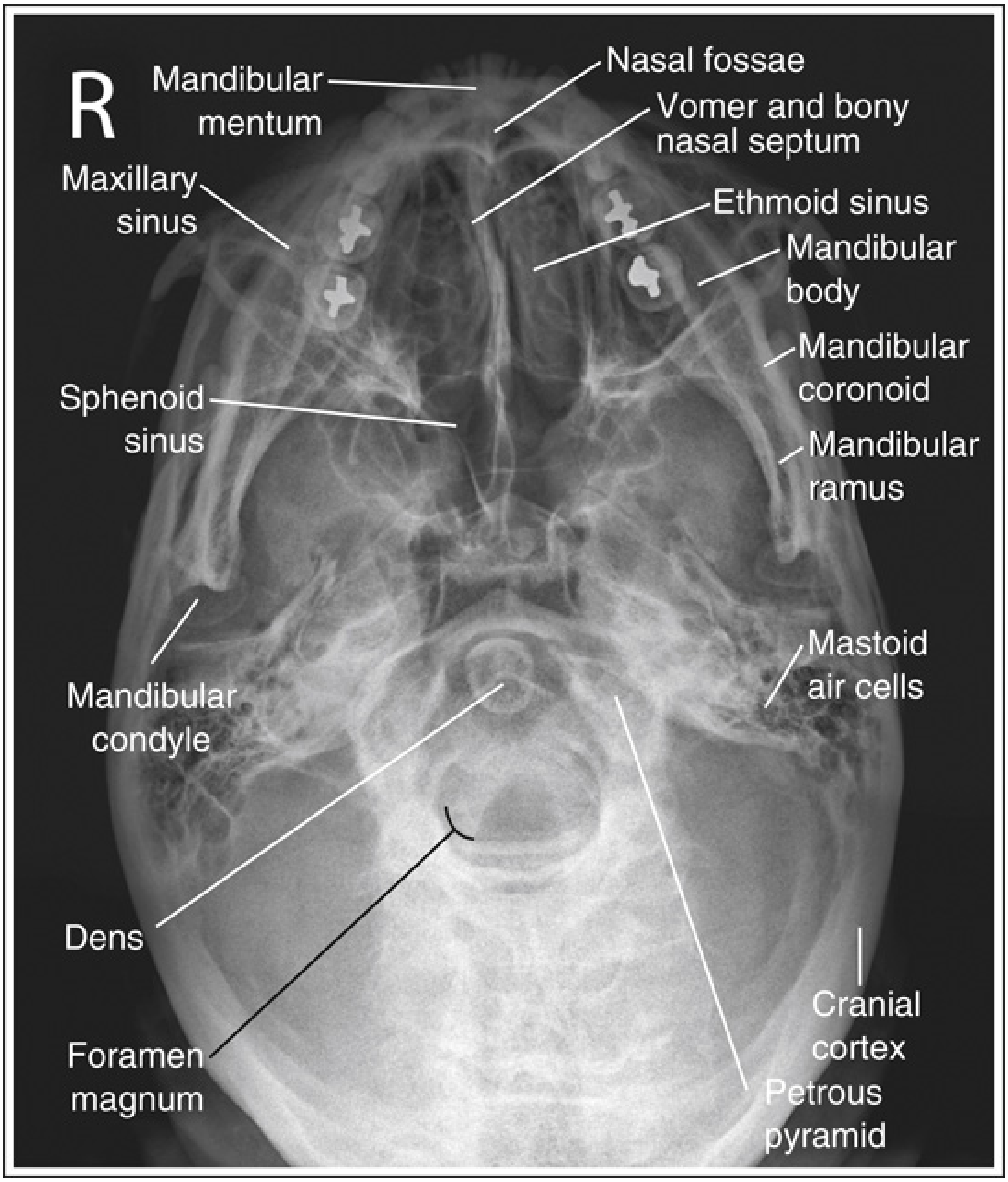


FIGURE 11.44 SMV cranial projection (Schueller method) with accurate positioning.

FIGURE 11.45 SMV sinus and mandible projection (Schueller method) with accurate positioning.

TABLE 11.7

AP, Anteroposterior; *CR*, central ray; *EAM*, external auditory meatus; *IOML*, infraorbitomeatal line; *IR*, image receptor; *SMV*, submentovertex.

IOML Alignment: Neck Overextended

Mispositioning of the mandibular mentum and ethmoid sinuses on a submentovertex (SMV) projection obscures the ethmoid sinuses, and foramen ovale and spinosum. If the neck was overextended, the mandibular mentum is demonstrated too far anterior to the ethmoid sinuses (**Fig. 11.47**).

IOML Alignment: Neck Underextended

If the neck was underextended, the mandibular mentum is superimposing or demonstrated posterior to the ethmoid sinuses (**Fig. 11.48**). For a patient with a retracted jaw, it may be necessary to raise the chin and extend the neck beyond the infraorbitomeatal line (IOML) to position the mandibular mentum anterior to the frontal bone. If the patient is unable to align the IOML parallel with the IR, extend the neck as far as possible and angle the CR cephalad until it is aligned perpendicular to the IOML.

Cranial Tilting

The cranium's midsagittal plane is aligned perpendicular to the IR to prevent cranial tilting on an SMV projection. Cranial tilting can be identified on an SMV projection of the head by comparing the distances from the mandibular ramus and body with the distance to the corresponding lateral cranial cortex on either side. If the head was not tilted, the distances are equal. If the head was tilted, the distance is greater on the side toward which the cranial vertex was tilted (**Fig. 11.49**).

FIGURE 11.46 Proper patient positioning for SMV cranial projection (Schueller method).

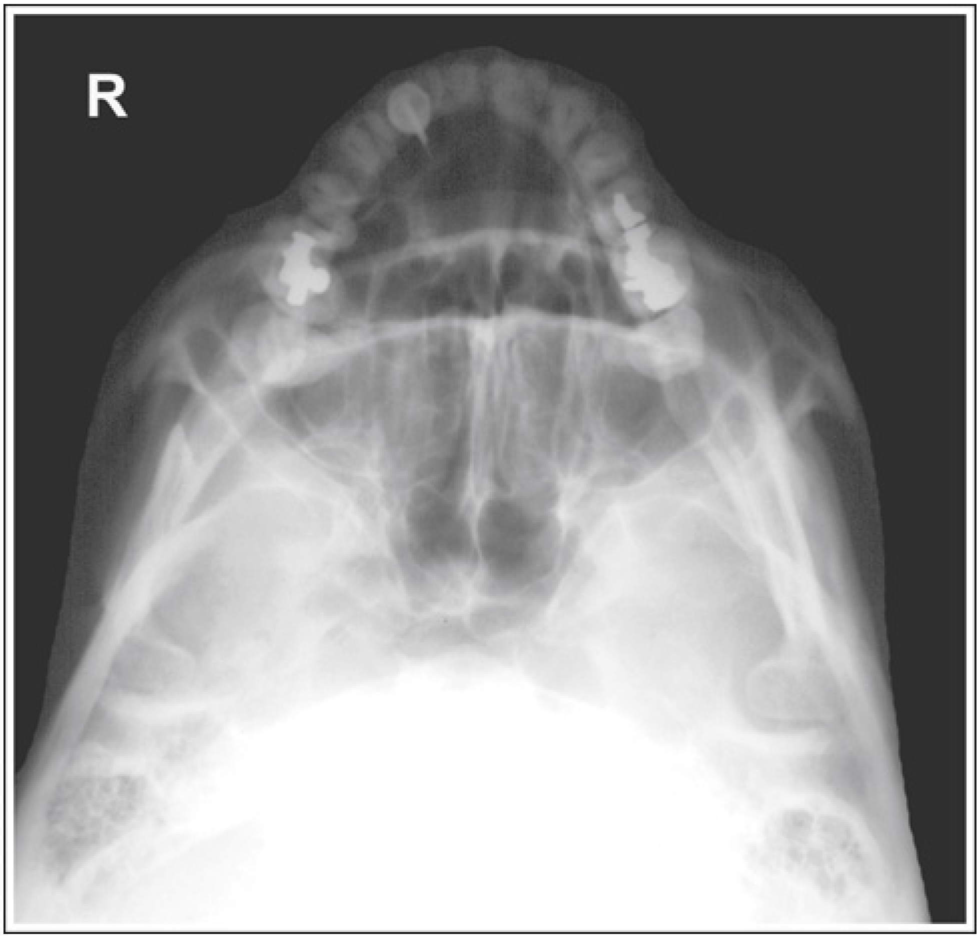


FIGURE 11.47 SMV cranial projection (Schueller method) taken with the neck overextended, positioning the chin at a higher level than the forehead.

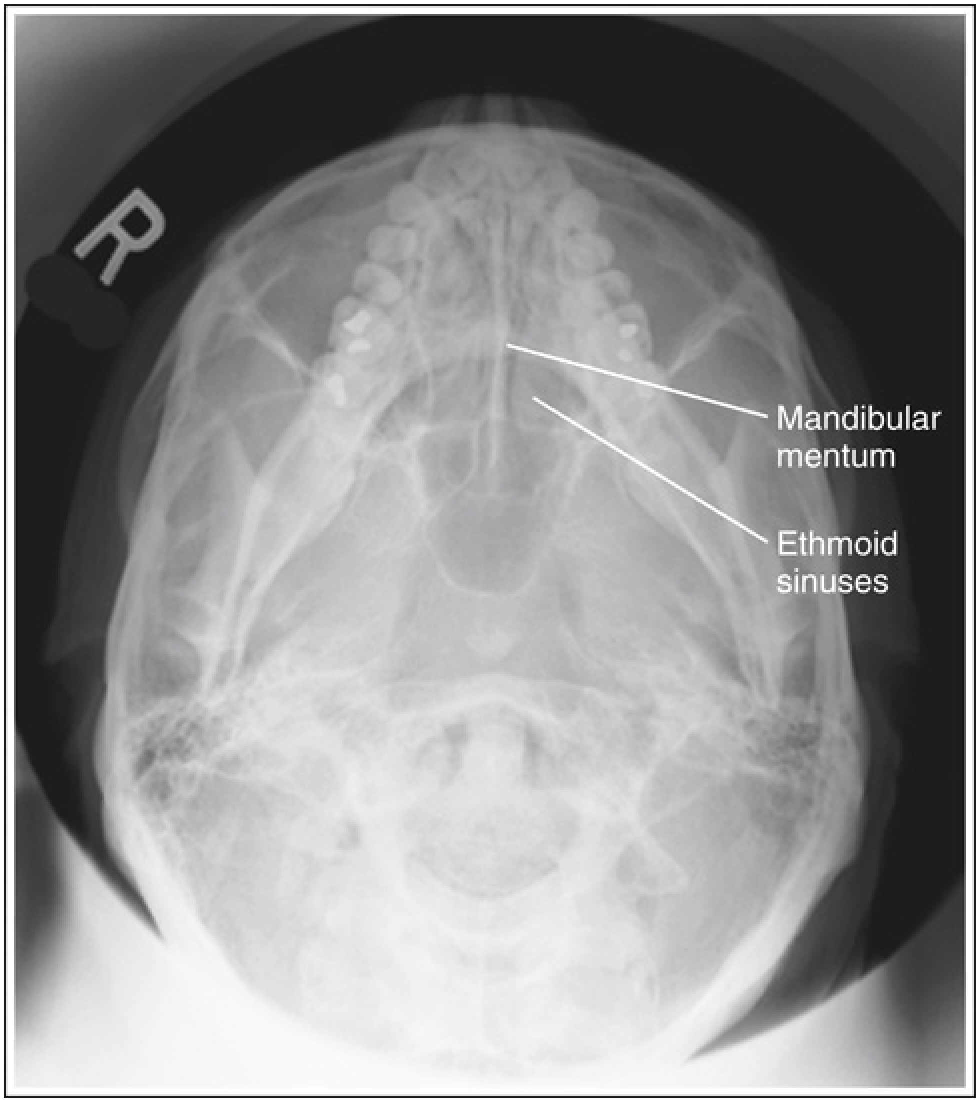


FIGURE 11.48 SMV cranial projection (Schueller method) taken with the neck underextended, positioning the chin at a lower level than the forehead.

FIGURE 11.49 SMV cranial projection (Schueller method) taken with the neck underextended, positioning the chin at a lower level than the forehead, and with the head tilted, positioning the top of the head toward the right side.

SMV Projection Analysis Practice

IMAGE 11.10

SMV CRANIUM PROJECTION.

Analysis

The distance from the right mandibular ramus and body to its corresponding lateral cranial cortex is greater than the distance from the left mandibular

ramus and body to its corresponding lateral cranial cortex. The cranial vertex was tilted toward the right side. The mandibular mentum is demonstrated posterior to the ethmoid sinuses. The neck was underextended, preventing the IOML from being positioned parallel with the IR.

Correction

Tilt the cranial cortex toward the left side until the cranium's midsagittal plane is perpendicular to the IR and elevate the chin until the IOML is aligned parallel with the IR.

Facial Bones and Sinuses: Parietoacanthial and Acanthioparietal Projection (Waters Method)

See **Table 11.8** and Figs. **11.50–11.52**.

Demonstrating Air-Fluid Levels

To demonstrate air-fluid levels within the maxillary sinus cavities, this projection must be taken with the patient in an upright position and using a horizontal CR.

Cranial Rotation

Head rotation is present on parietoacanthial and acanthioparietal projections when the distance from the lateral orbital margin to the lateral cranial cortex on one side is greater than the same distance on the other side (**Fig. 11.53**). The side of the cranium that the face is rotated toward will have the least distance.

MML Alignment: Insufficient Chin Elevation

Poor mentomeatal line (MML) positioning can be detected by evaluating the positions of the petrous ridges and posterior maxillary alveolar process. Chin elevation moves the maxillary sinuses superior to the petrous ridges. If the chin was not adequately elevated to bring the MML perpendicular to the IR, the petrous ridges are demonstrated superior to the posterior maxillary alveolar process superimposing the maxillary sinuses (**Figs. 11.54** and **11.55**).

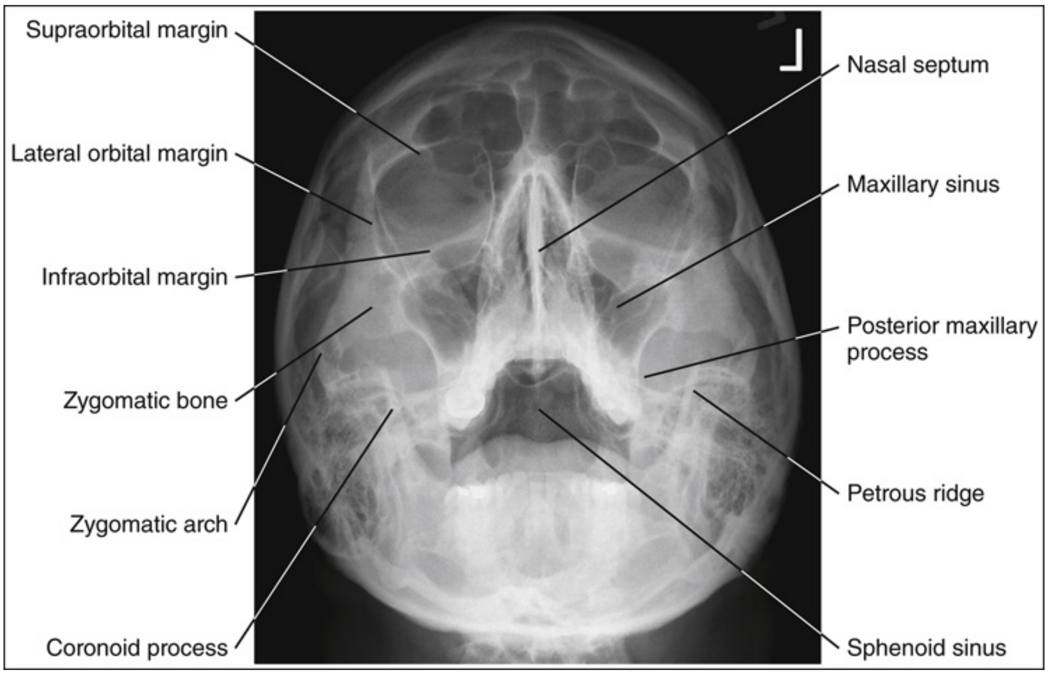


FIGURE 11.50 Parietoacanthial facial bone and sinus projection (Waters method) with accurate positioning.

TABLE 11.8

AP, Anteroposterior; *CR*, central ray; *IR*, image receptor; *MML*, mentomeatal line; *OML*, orbitomeatal line; *PA*, posteroanterior.

For a patient who is unable to elevate the chin adequately to position the MML perpendicular to the IR, the CR may be adjusted to compensate as long as the exam is not being taken to demonstrate air-fluid levels. Instruct the patient to elevate the chin to position the MML as close as possible to perpendicular to the IR. Then angle the CR until it is parallel with the OML and then adjust the CR 37 degrees from the OML in the direction that will angle it with the MML (**Fig. 11.56**) (cephalically for the acanthioparietal and caudally for the parietoacanthial projection).

FIGURE 11.51 Proper patient positioning for parietoacanthial facial bone and sinus projection (Waters method).

FIGURE 11.52 Proper patient positioning for open-mouth parietoacanthial sinus projection (Waters method).

FIGURE 11.53 Parietoacanthial sinus projection (Waters method) taken with the face rotated toward the left side and the chin insufficiently elevated to bring the MML perpendicular to the IR.

FIGURE 11.54 Parietoacanthial sinus projection with the face slightly rotated toward the left side and the chin insufficiently elevated to bring the MML perpendicular to the IR.

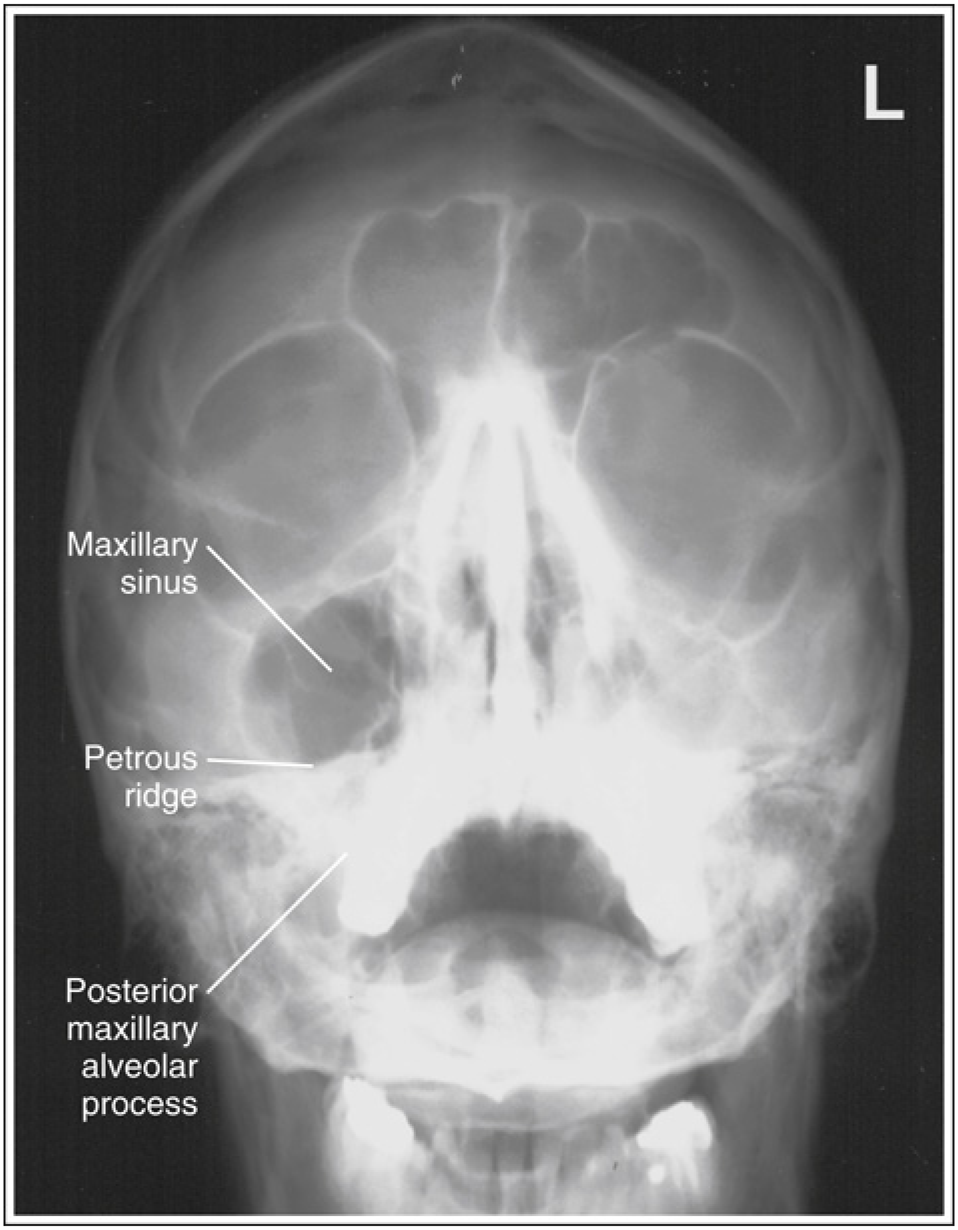


FIGURE 11.55 Acanthoparietal facial bone projection (Waters method) taken with the chin insufficiently elevated to bring the MML perpendicular to the IR.

Mentomeatal Line Alignment: Excessive Chin Elevation

If the chin was elevated more than needed to position the MML perpendicular to the IR, the petrous ridges are demonstrated inferior to the maxillary sinuses and posterior maxillary alveolar process, and the maxillary sinuses are superimposed over the posterior molars and alveolar process (**Fig. 11.57**).

Head Tilting and Midsagittal Plane Alignment

Head tilting causes the CR (and beam divergence) to align incorrectly with the anatomical structures and may result in a rotation (**Fig. 11.58**). It also prevents tight collimation.

Modified Waters Method

A modified Waters method is used to position the orbital floors perpendicular to the IR and parallel to the CR for increased demonstration of the orbital floors. This examination is commonly done to rule out fractures of the orbits and demonstrate foreign bodies in the eyes. The modified Waters method is accomplished by positioning the patient as described for the parietoacanthial and acanthioparietal projections, with one exception—the chin is elevated only until the OML is at a 55-degree angle with the IR (lips-meatal line [LML] is perpendicular to IR). In this position the petrous ridges will be demonstrated within the maxillary sinuses rather than inferior to them (**Fig. 11.59**).

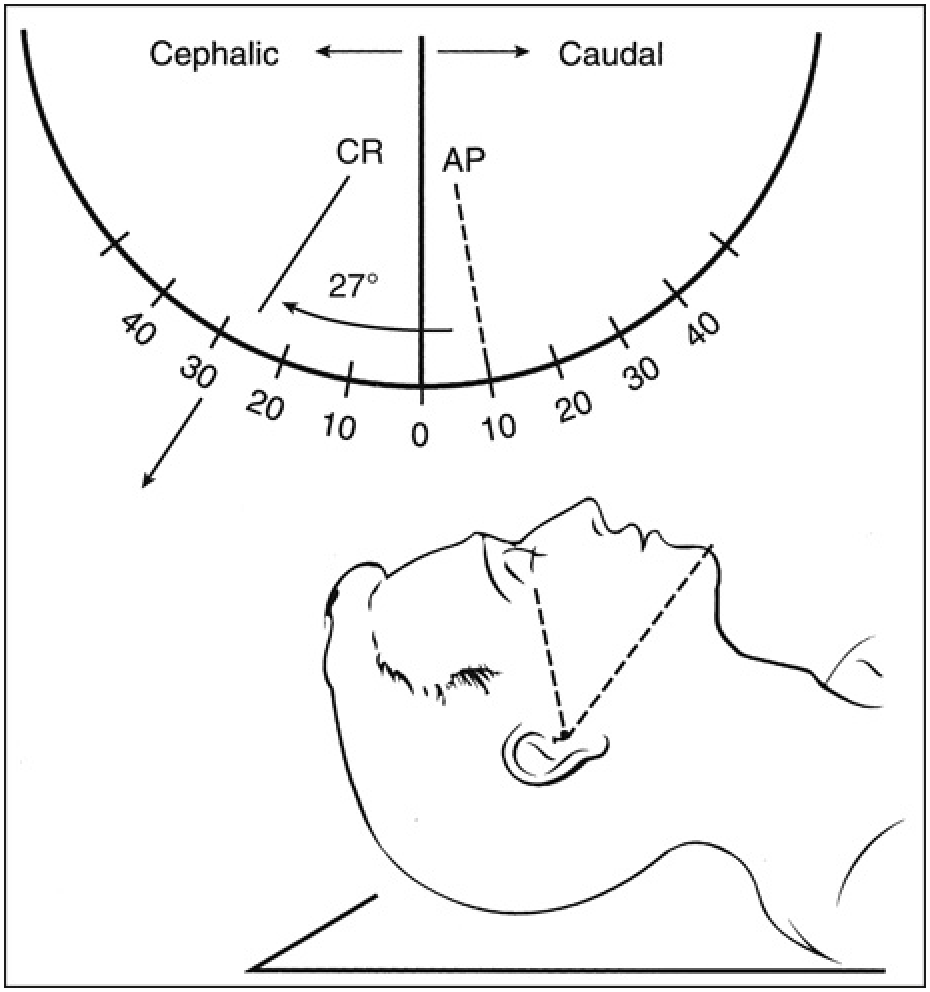


FIGURE 11.56 Determining central ray *(CR)* angle for acanthioparietal facial bone and sinus projection (Waters method) in a trauma patient.

FIGURE 11.57 Parietoacanthial sinus projection (Waters method) taken with the chin elevated more than needed to bring the MML perpendicular to the IR. The face is also slightly rotated toward the left side.

FIGURE 11.58 Parietoacanthial sinus projection (Waters method) taken with the head tilted and chin insufficiently elevated to bring the MML perpendicular to the IR.

FIGURE 11.59 Modified Waters facial bone and sinus projection with accurate positioning.

Parietoacanthial and Acanthioparietal Projection Analysis Practice

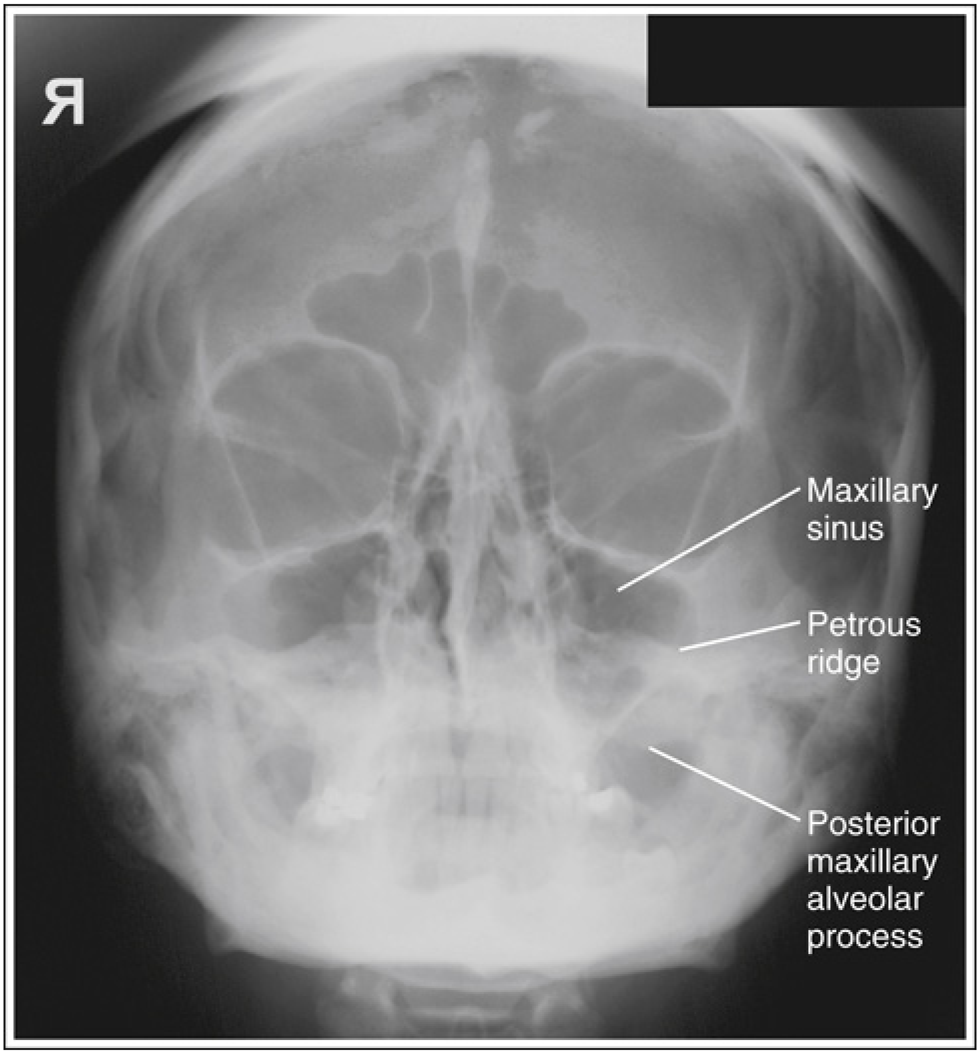


IMAGE 11.11

PARIETOACANTHIAL PROJECTION.

Analysis

The petrous ridges are demonstrated within the maxillary sinuses and superior to the posterior maxillary alveolar process. The chin was not elevated enough to position the MML perpendicular to the IR or the CR was angled too cephalically. The distance from the right lateral orbital

margin to the lateral cranial cortex is greater than the same distance on the left side. The face was rotated toward the right side.

Correction

Elevate the chin until the MML is perpendicular to the IR. If the patient is unable to elevate the chin further, leave the chin positioned as it is and angle the CR caudally until it is aligned with the MML when the mouth is closed. Rotate the face toward the left until the midsagittal plane is perpendicular to the IR.

Bibliography

1. Adler A, Carlton R. *Introduction to radiologic sciences and patient care* . 7th ed. St Louis: Saunders; 2018.
2. Bontrager K, Lampignano J. *Bontrager's textbook of radiographic positioning and related anatomy* . 10th ed. St Louis: Elsevier; 2021.
3. Bushberg J.T, Seibert J.A, Leidholdt E.M, et al. *The essential physics of medical imaging* . 4th ed. Wolters Kluwer; 2021.
4. Bushong S.C. *Radiologic science for technologists: Physics, biology, and protection* . 11th ed. St Louis: Elsevier; 2017.
5. Carroll Q.B. *Radiography in the digital age* . 3rd ed. Springfield, IL: Charles C Thomas; 2018.
6. Carter C.E, Veale B.L. *Digital radiography and PACS* . 3rd ed. St Louis: Elsevier; 2018.
7. Conn K.S, Clarke M.T, Hallett J.P. A simple guide to determine the magnification of radiographs and to improve the accuracy of preoperative templating. *Journal Bone Joint Surgery* . 2002;84-B(2):269–272.
8. Ehrlich R.A, Coakes D.M. *Patient care in radiography* . 10th ed. St Louis: Elsevier; 2020.
9. Fauber T.L. *Radiographic imaging and exposure* . 6th ed. St Louis: Elsevier; 2022.
10. Frank E.D, et al. Mayo clinic: Radiography of the ankle mortise. *Radiologic Technology* . 1991;62:354–359.

11. Fraser R.G, Colman N, Muller N, et al. *Synopsis of diseases of the chest* . 3rd ed. Philadelphia: Saunders; 2005.
12. Hobbs D.L. Chest radiography for radiologic technologists. *Radiologic Technology* . 2007;78:494–516.
13. Jeffrey R.B, Ralls P.W, Leung A.N, et al. *Emergency imaging* . Philadelphia: Lippincott Williams & Wilkins; 1999.
14. Long B.W, Smith B.J, Rollins J.H. *Merrill's atlas of radiographic positioning and radiologic procedures* . 14th ed. St Louis: Elsevier; 2018.
15. McHugh K.M. Positioning total knee replacements. *Radiologic Technology* . 2008;80(1):83–86.
16. Moore Q.T, Steven D, Goske M.J, et al. Image gently: Using exposure indicators to improve pediatric digital radiography. *Radiologic Technology* . 2012;84(1):93–99.
17. Rogers L.F. *Radiology of skeletal trauma* . 3rd ed. New York: Churchill Livingstone; 2002.
18. Scott A.M. Total knee replacement and imaging. *Radiologic Technology* . 2015;87(1):65–90.
19. Shephard C.T. *Radiographic image production and manipulation* . New York: McGraw-Hill; 2003.
20. Standring S. *Gray's anatomy: The anatomical basis of clinical practice* . 41st ed. St Louis: Churchill Livingstone; 2015.
21. Statkiewicz M.A, Visconti P.J, Ritenour E.R, et al. *Radiation protection in medical radiography* . 9th ed. St Louis: Elsevier; 2021.
22. Thornton A, Gyll C. *Children's fracture: A radiological guide to safe practice* . London: Baillière Tindall; 2000.

23. Tortora G.J, Derrickson B.H. *Principles of anatomy and physiology* . 16th ed. New York: John Wiley & Sons; 2020.

24. Ward R, Blickman H. *Pediatric imaging* . St Louis: Mosby; 2005.

25. Williamson S.L. *Primary pediatric radiology* . Philadelphia: Saunders; 2002.

Glossary

abduct To move an extremity outward, away from the torso. The humerus is abducted when it is elevated laterally.

abductor tubercle Round bony structure located posteriorly on the medial aspect of the femur, just superior to the medial condyle.

acanthiomeatal line Imaginary line connecting the point where the upper lip and nose meet with the external ear opening.

additive condition Condition that results in change to the normal bony structures, soft tissues, or air or fluid content of the patient; may require technical changes to compensate for them prior to exposing the patient. Additive diseases cause the tissues to increase in atomic density or thickness, making them more radiopaque.

adduct To move an extremity toward the torso. The humerus is adducted when it is positioned closer to the torso after being abducted.

ALARA Acronym for keeping radiation exposure " ***a*** s ***l*** ow ***a*** s ***r*** easonably ***a*** chievable."

algorithm Set of rules or directions used by the computer for getting a specific outcome from a specific input.

annotation Adding markers (e.g., R or L side, text words) to the radiograph after the exposure has been made from the computer display monitor.

anode heel effect Absorption of radiation in the heel of the anode, resulting in less x-ray intensity at the anode side of a long IR as compared with the cathode side.

anterior (antero-) Refers to the front surface of the patient; used to express something situated at or directed toward the front; includes the palms and tops of the feet as in anatomic position. *The sternum is anterior to the vertebral column*.

anterior shoulder dislocation Condition in which the humeral head is demonstrated anteriorly beneath the coracoid.

artifact Undesirable structure or substance recorded on the image. It may or may not be covering the VOI.

atomic density The concentration of atoms within a given tissue space.

augmentation mammoplasty A surgical procedure where breast implants are added for reconstructive purpose or cosmetic reasons to enhance the size and shape of the breasts.

automatic exposure control (AEC) System used in radiography that automatically stops the exposure time when adequate IR exposure has been reached.

automatic implantable cardioverter/defibrillator (ICD) Used to detect heart arrhythmias and then deliver an electrical shock to the heart to convert it to a normal rhythm.

automatic rescaling Final phase of image processing in digital radiography during which the computer compares the image histogram with the selected lookup table (LUT) and applies algorithms to the raw data to align the image histogram with the LUT.

axilla Armpit.

backup timer Maximum time that the x-ray AEC will be allowed to continue before shutting off automatically.

base of support (BOS) Area of the ground surface on which the feet are resting. The center of the BOS is between the feet.

bilateral Both sides.

bit depth Determines the maximum range of pixel values the computer can store. The values signify the gray scale that is available to create the digital image.

body habitus Body physique or type. The designations hypersthenic, sthenic, asthenic, and hyposthenic habitus are used in radiography to determine the size of image receptor to use and the locations of the thoracic and peritoneal structures.

bony trabeculae Supporting material in cancellous bone. Trabeculae are demonstrated on images as thin white lines throughout a bony structure and are evaluated for changes.

breathing technique Technique in which a long exposure time (3 to 4 seconds) is used with costal breathing to blur the lung details surrounding the bony structures of interest.

brightness The degree of luminance seen on the display monitor; refers to the degree of lightness (white) or lack of lightness (black) of the pixels in the image.

carpal canal Wrist passageway formed anteriorly by the flexor retinaculum, posteriorly by the capitate, laterally by the scaphoid and trapezium, and medially by the pisiform and hamate.

caudal Foot end of the patient. A caudally angled central ray is directed toward the patient's feet.

center of gravity (COG) A point in the center of the pelvis that is a little above the hip joints and anterior to the second sacral vertebra; it is where the weight is equally distributed on all sides.

central ray (CR) Center of the x-ray beam. It is used to center the anatomic structure and IR.

central venous catheter (CVC) Catheter used to allow infusion of substances that are too toxic for peripheral infusion, as for chemotherapy, total parenteral nutrition, dialysis, or blood transfusion.

cephalic Head end of the patient. A cephalically angled CR is directed toward the patient's head.

concave Curved or rounded inward. The anterior surface of the metacarpals is concave.

contrast Difference in brightness level in tissues that have different degrees of absorption.

contrast mask A postprocessing manipulation that adds a black background over the areas outside the VOI to eliminate them and provide a perceived enhancement of image contrast.

contrast resolution The ability of an imaging system to distinguish between details by displaying them with different gray shades.

convex Curved or rounded outward. The posterior surface of the metacarpals is convex.

cortical outline Outer layer of a bone demonstrated on an image as the white outline of an anatomic structure.

costal breathing Slow, shallow breathing; used with a long exposure time to blur chest details.

decubitus Refers to the patient lying on a table or cart while a horizontally directed CR is used; the term *decubitus* is also used to refer to the surface (lateral, dorsal, or ventral) placed adjacent to the table or cart. *The patient is in a left lateral decubitus position*.

density Degree of darkness in an image.

depress To lower or sink down, positioning at a lower level.

destructive condition Condition that results in change to the normal bony structures, soft tissues, or air or fluid content of the patient; technical changes may be required to compensate for them prior to exposing the patient. Destructive diseases cause the tissues to lose density or thickness, so that they become more radiolucent.

detector element (DEL) Element in the DR image receptor containing the electronic components that store the detected energy.

deviate To move away from the normal or routine.

differential absorption Radiographic contrast caused by differences in the atomic density, atomic number, and thickness composition of the patient's body parts and how each type of tissue absorbs x-ray photons.

distal (disto-) Refers to a structure that is situated away from the source or beginning. The foot is distal to the ankle, or the splenic flexure is distal to the hepatic flexure.

distortion Misrepresentation of the size or shape of the structure being examined.

dorsal (dorso-) See posterior.

dorsiflexion Backward bending, as of the hand or foot; brings the toes and forefoot upward.

dorsoplantar projection X-ray beam that enters the top of the patient's foot and exits through the bottom of the foot.

dose creep When technique values (mAs, kV) are elevated more than necessary owing to fear of producing images with quantum noise.

dose equivalent limits Maximum permissible radiation dose limits; used for radiation protection purposes.

dynamic range Range of gray shades that the imaging system can display; measured by the bit depth of each pixel.

elevate To lift up or raise; position at a higher level.

elongation To make one axis of an anatomic structure appear disproportionately longer on the image than the opposite axis. Angling the CR while the part and IR remain parallel with each other will elongate the axis toward which the CR is angled.

endotracheal tube (ETT) Stiff, thick-walled tube used to inflate the lungs.

entrance skin exposure (ESE) Absorbed dose to the most superficial layers of skin.

eversion Act of turning the plantar foot surface as far laterally as the ankle will allow.

exposure field recognition Computed radiography process in which the computer distinguishes the raw data representative of information within the exposure field from that which comes from outside the exposure field so that proper automatic rescaling can occur.

exposure indicator (EI) Readings obtained in digital radiography that express the amount of IR exposure given off by the IP; indicates the amount of radiation exposure to the patient and IP.

exposure maintenance formula Formula used to adjust the mAs the needed amount to maintain the required IR exposure and prevent quantum noise: (new mAs)/(old mAs) = (new distance squared)/(old distances squared).

extension Movement that results in the straightening of a joint. With extension of the elbow, the arm is straightened. Extension of the cervical vertebrae shifts the patient's head posteriorly in an attempt to separate the vertebral bodies.

external auditory meatus (EAM) External ear opening.

external (lateral) rotation Act of turning the anterior surface of an extremity outward or away from the midline of a patient's torso.

fat pads Accumulation of adipose or fatty tissue that, by its displacement, can indicate joint effusion on radiographic images.

field of view (FOV) Area of the image receptor from which the image data are collected. For computed radiography, the area is the entire imaging plate; for direct or indirect capture radiography, it is the detectors that are included in the exposure field as determined by collimation.

flexion Movement that bends a joint. With flexion of the elbow, the arm is bent. Flexion of the cervical vertebrae shifts the patient's head forward in an attempt to bring the vertebral bodies closer together.

foreshorten To make one axis of an anatomic structure appear disproportionately shorter on the image than the opposite axis. Positioning the long axis of the lower leg at a 45-degree angle with the IR while the CR is perpendicular to the IR foreshortens the image of the lower leg.

frog-leg position Position where the affected leg is flexed and abducted to demonstrate a lateral projection of the hip and proximal femur.

glabelloalveolar line Imaginary line connecting the glabella and alveolar ridge.

gluteal fat plane The fat plane superior to the femoral neck.

gray scale Number of gray shades used between white and black to display the radiographic image. A long gray scale indicates that there are many shades; a short gray scale indicates that there are few shades.

grid Device consisting of lead strips placed between the patient and IR to reduce the amount of scatter radiation reaching the receptor.

grid cutoff Reduction in the amount of primary radiation reaching the IR because of grid misalignment.

Hill-Sachs defect Defect in the notch of the posterolateral humeral head created by impingement of the articular surface of the humeral head against the anteroinferior rim of the glenoid cavity.

histogram Graph generated from the raw data that has the pixel brightness value on the *x*-axis and the number of pixels with that brightness value on the *y*-axis.

histogram analysis error Image histogram that includes raw data values in the VOI that should not be included; this results in a misshapen histogram that will not match the lookup table closely enough for the computer to rescale the data accurately.

homogeneous Refers to uniformity among structures.

iliopsoas fat plane Fat plane that lies within the pelvis medial to the lesser trochanters.

image acquisition Process of collecting x-ray transmission measurements from the patient.

image receptor (IR) Device that receives the radiation leaving the patient. Computed radiography uses an imaging plate and the DR system uses detector elements.

imaging plate (IP) 1. Plate used in computed radiography coated with a photostimulable phosphor material that absorbs the photons exiting the patient, resulting in the formation of a latent image that is released and digitized before being sent to a computer. 2. A thin flexible sheet of plastic with a photostimulable phosphor layer that is placed inside the computed radiography cassette to record the radiographic image; computed radiography's image receptor.

inferior (infero-) Refers to a structure within the patient's torso that is situated closer to the feet; used in comparing the locations of two structures. *The symphysis pubis is inferior to the iliac crest*.

infraorbital Below the orbits.

infraorbitomeatal line (IOML) Imaginary line connecting the inferior orbital margin and EAM.

interiliac line Imaginary line connecting the iliac crests.

intermalleolar line Imaginary line drawn between the medial and lateral malleoli.

internal (medial) rotation Act of turning the anterior surface of an extremity inward or toward the midline of the patient's torso.

interpupillary line Imaginary line connecting the outer corners of the eyelids.

intraperitoneal air Presence of free air in the abdominal cavity.

inverse square law Law that states that radiation intensity is inversely proportional to the square of its distance from the x-ray source.

inversion Act of turning the plantar foot surface as far medially as the ankle will allow.

involuntary motion Movement that the patient cannot control.

ionization chamber Chamber in the AEC system that collects radiation. For adequate IR exposure to result, the appropriate chamber must be selected for the part being imaged.

joint effusion Escape of fluid into the joint.

kyphosis Excessive posterior convexity of the thoracic vertebrae.

lateral (latero-) Refers to the patient's sides; used to express something that is directed or situated away from the patient's median plane or to express the outer side of an extremity. *The kidneys are lateral to the vertebral column; place the IR against the lateral surface of the knee*.

lateral mortise Talofibular joint.

lateral position Refers to positioning of the patient so that the side of the torso or extremity being imaged is placed adjacent to the IR. When a lateral position of the torso, a vertebra, or the cranium is defined, the term *right* or *left* is also included to state which side of the patient is placed closer to the IR. *The patient was in a left lateral position when the chest projection was taken*.

law of isometry Used to minimize shape distortion in imaging long bones when the bone and IR cannot be positioned parallel. The law of isometry indicates that the CR should be set at half the angle formed between the bone and IR.

line of gravity (LOG) An imaginary plane that runs the length of the body, through the center of gravity, and down to the ground, dividing the body into two equal halves.

lips-meatal line Imaginary line connecting the lips (with mouth closed) with the EAM.

longitudinal foreshortening Is present when the long axis of a structure appears disproportionately shorter on the image than the short axis.

lookup table (LUT) Histogram of the brightness and contrast values of the ideal image. It is used as a reference to evaluate the raw data of similar images and automatically rescales their values when needed to match those in the LUT.

magnification Proportionately increasing or enlarging both axes of a structure. The gonadal contact shield is magnified on the image if it is placed on top of the patient.

mammary line Imaginary line connecting the nipples.

manual exposure When the technical factors (mAs, kV) are set based on the patient's thickness measurement.

matrix Columns and rows of pixels (array) that divide a digital pixel.

medial (medio-) Refers to the patient's median plane; used to express something that is directed or situated toward the patient's median plane or to express the inner side of an extremity. *The sacroiliac joints are medial to the anterior superior iliac spines (ASISs); Place the IR against the medial surface of the knee*.

mentomeatal line Imaginary line connecting the chin with the EAM.

midcoronal plane Imaginary plane that passes through the body from side to side and divides it into equal anterior and posterior sections

or halves.

midsagittal or median plane Imaginary plane that passes through the body anteroposteriorly or posteroanteriorly and divides it into equal right and left sections or halves.

minimal response time Shortest exposure time to which the AEC can respond and still produce an acceptable image.

moiré grid artifact Wavy-line artifact that occurs when a stationary grid is used in computed radiography and the imaging plate is placed in the plate reader so that the grid's lead strips align parallel with the scanning direction.

motion unsharpness The lack of detail and sharpness on a projection caused by the patient's movement during the exposure.

noise Any nonuseful input to the projection that will interfere with the visibility of the VOI. Artifacts, scatter radiation, quantum mottle, and electronic noise are examples.

nonstochastic effect Biologic response of radiation exposure that can be directly related to the dose received.

object–image receptor distance (OID) Distance from the object being imaged to the IR.

oblique Refers to rotation of a structure away from an AP or PA projection. When obliquity of the torso, vertebrae, or cranium is defined, the terms *right* or *left* and *anterior* or *posterior* are used with the term *oblique* to indicate which side of the patient is placed closer to the IR. In a right anterior oblique (RAO) position the patient is rotated so that the right anterior surface is placed closer to the IR. When obliquity of an extremity is defined, the term *medial* (internal) or *lateral* (external) is used with the term *oblique* to

indicate which way the extremity is rotated from anatomic position and which side of the extremity is positioned closer to the IR. For a medial oblique position of the wrist, the medial side of the arm is placed closer to the IR.

obturator internus fat plane Fat plane lying within the pelvic inlet next to the medial brim.

occlusal plane Chewing surface of the maxillary teeth.

orbitomeatal line Imaginary line connecting the canthus of the outer eye and the EAM.

pacemaker A device used to regulate the heart rate by supplying electrical stimulation to it. This electrical signal will stimulate the heart to the degree needed to maintain an effective rate and rhythm.

palmar Referring to the anterior surface of the hand.

pericapsular fat plane A fat plane around a joint.

phantom image Artifact that occurs in computed radiography when the imaging plate is not erased adequately before the next image is exposed and two images are recorded onto the plate phosphor.

photon flux The number of photons striking a specific area per unit of time.

picture archival and communication system (PACS) A system whereby the digitized images from all the different modalities in a facility (RT, CT, MRI, etc.) are stored and can be retrieved, displayed, and transmitted to computers on the local area network (LAN).

pixel Single cell within a matrix.

plantar Pertaining to the sole of the foot.

plantarflexion The act of moving the toes and forefoot downward.

pleural drainage tube Thick-walled tube used to remove fluid or air from the pleural space, which could result in collapse of the lung.

pleural effusion Fluid in the pleural cavity.

pneumectomy Removal of a lung.

pneumothorax Presence of air in the pleural cavity.

postprocessing Adjustments made to the image at the console by the technologist, including windowing for brightness and contrast, edge enhancement, adding annotations, image reorientation (turning or flipping), and zooming.

posterior (postero-) Refers to the back of the patient; used to express something that is situated at or directed toward the back and includes the backs of the hands and bottoms of the feet, as in anatomic position. *The knee joint is posterior to the patella*.

posterior shoulder dislocation Shoulder condition in which the humeral head is demonstrated posteriorly, beneath the acromion process.

prevertebral fat stripe Fat stripe located anterior to the cervical vertebrae.

procedural algorithm Computer software indicating the dynamic range and average brightness levels for the computer to use in displaying a projection. These are embedded in the LUTs used when the histogram is automatically rescaled to optimize the anatomic structures for that projection.

profile Outline of an anatomic structure. The glenoid fossa is demonstrated in profile on a Grashey method image.

project The act of throwing the image of an anatomic structure forward. An angled CR projects the anatomic part situated farther away from the IR than the anatomic part situated closer to the IR.

projection Term used to describe the entrance and exit points of the x-ray beam as it passes through the body when an image is taken. In a projection, the path from the first location to the second must be a straight line. These include anteroposterior, inferosuperior, lateromedial, mediolateral, posteroanterior, and superoinferior projections.

pronate To rotate or turn the upper extremity medially until the hand's palmar surface is facing downward or posteriorly.

pronator fat stripe Soft tissue structure demonstrated on lateral wrist images located parallel to the anterior surface of the distal radius.

protract To move a structure forward or anteriorly. The shoulder is protracted when it is drawn forward.

proximal (proximo-) Refers to a structure that is closest to the source or beginning. *The shoulder joint is proximal to the elbow joint; the hepatic flexure is proximal to the splenic flexure*.

pulmonary arterial catheter Catheter used to measure atrial pressures, pulmonary artery pressure, and cardiac output.

quantum noise (mottle) Graininess or random pattern that is superimposed on the image, obscuring information. It is present when photon flux is insufficient.

radial deviation While maintaining a PA projection, the distal hand is moved toward the radial side as much as the wrist will allow.

radiolucent Allowing the passage of x-radiation. A radiolucent object appears dark on an image.

radiopaque Preventing the passage of x-radiation. A radiopaque object appears white on an image.

raw data Brightness values that have come from the digital IR before rescaling occurs.

recorded detail Sharpness of structures that have been included on the image.

recumbent Lying down.

resolution Differentiation of individual structures or details from one another on an image.

retract To move a structure backward or posteriorly. The shoulder is retracted when it is drawn backward.

saturation Demonstrated on an image as a loss of contrast resolution, with some or all of the structures demonstrating a black shade. The postprocessing technique of windowing cannot restore the saturated area.

scaphoid fat stripe Soft tissue structure demonstrated on wrist images located just lateral to the scaphoid.

scatter radiation Radiation that has changed in direction from the primary beam because of an interaction with the patient or another structure. Because it is emitted in a random direction, it carries no useful signal or subject contrast.

scoliosis Spine condition that results in the vertebral column's curving laterally instead of running straight.

signal-to-noise ratio (SNR) The ratio between the desired signals and the undesired signals, where the desired signals represent the remnant beams of the VOI and the undesired (noise) signals represent the scattered radiation, quantum mottle, and electronic

static in the image. An increase in SNR indicates that more desired than undesired signals were used to create the image.

source–image receptor distance (SID) Distance from the anode's focal spot to the IR.

source–object distance (SOD) Distance from the anode's focal spot to the patient.

source–skin distance (SSD) Distance from the source of radiation (anode) to the patient's skin. Good radiation practice dictates that this distance must be at least 12 inches (30 cm) to prevent unacceptable entrance skin exposure.

spatial frequency Used to define spatial resolution; refers to how often the number of details change in a set amount of space. It is expressed as line pairs per millimeter (lp/mm).

spatial resolution Ability of an imaging system to distinguish small adjacent details from each other in the image.

stochastic effect Biologic response to radiation in which the chance of occurrence of the effect, rather than the severity of the effect, is proportional to the dose of radiation received.

subject contrast Contrast caused by the x-ray attenuating characteristics (atomic density and number, and thickness) of the subject being imaged.

subluxation Partial dislocation.

superimpose To lie over or above an anatomic structure or object.

superior (supero-) Refers to a structure within the patient's torso that is situated closer to the head; used in comparing the locations of two torso structures. *The thoracic cavity is superior to the peritoneal cavity*.

supination Rotating or turning the upper extremity laterally until the hand's palmar surface is facing upwardly or anteriorly.

supraorbital Above the orbit.

supraspinatus outlet Opening formed between the lateral clavicle, acromion process, and superior scapula when the patient is positioned for a tangential outlet projection of the shoulder.

symmetric Refers to structures on opposite sides demonstrating the same size, shape, and position.

talar dome Dome shape formed by the most medial and lateral aspects of the talus's trochlear surface when it is in a lateral position.

tarsi sinus Opening between the calcaneus and talus.

thin-film transistor (TFT) Component in direct/indirect capture radiography that collects the electric chargers produced in the detector elements when the remnant radiation strikes it.

trabecular pattern Supporting material within cancellous bone. It is demonstrated on an image as thin white lines throughout a bony structure.

transverse foreshortening Exists when the short axis of a structure appears disproportionately shorter on the image than the long axis.

ulnar deviation While maintaining a PA projection, the distal hand is turned toward the ulnar side as much as the wrist will allow.

umbilical artery catheter (UAC) Employed only in neonates because the cord has dried up and fallen off in older infants. It is used to measure oxygen saturation.

umbilical vein catheter (UVC) Catheter used to deliver fluids and medications.

unilateral One sided.

valgus deformity Knee deformity in which the lateral side of the knee joint is narrower than the medial side.

values of interest (VOI) Brightness values (raw data) that represent only the anatomic structures of interest in digital radiography.

varus deformity Knee deformity in which the medial side of the knee joint is narrower than the lateral side.

vascular lung markings White markings in the lung fields that indicate blood vessels on a chest x-ray.

ventral (ventro-) See anterior.

voluntary motion Motion that the patient is able to control.

weight-bearing Describing a structure that is bearing weight, as with a standing lateral foot or AP knee projection.

windowing Postprocessing manipulation of an image's brightness and contrast to better demonstrate the VOI.

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